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# PAPERS AND PROCEEDINGS

OF

# The Royal Society of Tasmania

## Volume 94

Edited by William Bryden

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# The Royal Society of Tasmania

Volume 94

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# Royal Society of Tasmania

## Papers and Proceedings Volume 94

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# Royal Society of Tasmania

*Annual Report for the Year ended 31st December, 1959.*

The Society was honoured when His Excellency the Governor of Tasmania, the Right Honourable the Lord Rowallan, signified his willingness to accept the office of President of the Society. In passing it is interesting to note that since 1843, when the Society was formed by the then Lieutenant-Governor of the State, the office of President has been filled by successive Governors.

The year under review can be considered satisfactory from the Society's point of view. The membership total reached 558, of whom 204 were listed on the Northern Branch centred at Launceston.

### Annual Meeting.

At the Annual General Meeting of the Society held on 3rd March, 1959, the following office-bearers were elected:—

*Vice-President*: Under the Society's Rules, Mr. J. W. C. Wyett retired from the Office of Vice-President and Dr. D. Martin was elected to the vacancy.
*Honorary Secretary and Librarian*: Dr. W. Bryden.
*Honorary Treasurer*: Mr. G. E. A. Hale.
*Honorary Auditor*: Mr. A. M. Hewer.
*Council*: Under Rule 21, Mr. C. Bisdee and Dr. W. E. L. H. Crowther retired from the Council and Mr. J. W. C. Wyett and Mr. M. S. R. Sharland were elected for a period of three years.

At the conclusion of the special business associated with the annual meeting Mr. K. R. von Stieglitz, O.B.E., delivered a lecture, illustrated with slides, on "Early Settlement on the Clyde".

### R. M. Johnston Memorial Medal.

The Council invited Sir Edmund Hillary to deliver the R. M. Johnston Memorial Lecture and to receive the Memorial Medal. The function was held in the Town Hall, Hobart, on Wednesday, 24th June, 1959, and the presentation was made by His Excellency the Administrator, Sir Stanley Burbury. After the presentation Sir Edmund addressed the Society, his subject being "Crossing Antarctica".

### General Meetings.

Other meetings were held during the year and lectures were given by the following:—

April: "The Eucalypts in Ireland" by Dr. D. Martin.
May: "Some Effects of Automation and Cybernetics on Leadership and Management" by Mr. V. G. Burley.
June: "Some Recorded Songs of the Tasmanian Aborigines" by Mr. M. Longman.
July: "The Engravings of Early Van Diemen's Land" by Dr. C. Craig.
August: "Some Aspects of Higher Education in the U.S.A." by Mr. A. H. Spry.
September: "Canoeing on the Franklin River" by Dr. J. G. Hawkins.
October: "Arboreta and Botanic Gardens in Southern California" by Dr. William S. Stewart of Los Angeles State and County Arboretum.
November: "The History of the Thylacine or Tasmanian Tiger" by Dr. E. R. Guiler.

### Council.

The Council of the Society met at various times during the year, one of the meetings being held in Launceston when the Council of the Northern Branch acted as hosts.

### Committees, &c.

The following appointments for the year were made by Council:—

Standing Committee: Mr. L. W. Miller, Dr. E. R. Guiler, Mr. G. H. Stancombe, and Dr. W. Bryden, Honorary Secretary.
Representatives on the Trustees of the Tasmanian Museum and Art Gallery: Professor A. Burn and Mr. G. F. Davies.
Representative on the Trustees of the Botanical Gardens: Mr. Guy Barrett.
Representative on the Nomenclature Board: Mr. E. R. Pretyman.
Representative on the Mount Field National Park Board: Dr. D. Martin.
Representative to the Library Association of Tasmania: Dr. W. Bryden.

### Honorary Membership.

Mr. S. Angel was elected to Honorary Membership at the March meeting of the Society. As mentioned in the last Annual Report, Mr. Angel served this Society with outstanding interest for twenty years.

### Library.

Four hundred and sixty volumes (books and journals) were added to the Library during the year. There are now 32,194 volumes in the Library and the number of Institutions on the Exchange List is 315.

### Papers and Proceedings.

The ninety-third volume of the "Papers and Proceedings" was published during the year under review.

### Thanks.

The thanks of the Society are extended to the Government of Tasmania and to the University of Tasmania, to the donors of books, prints, documents, &c., and to all who have assisted the Society during the year.

# Northern Branch

*Annual Report*, 1959.

The Annual General Meeting of the Northern Branch of the Royal Society of Tasmania was held at the Queen Victoria Museum on 20th March, 1959, when the following were elected to the Branch Council:

Members of Council (1959-60): Mr. T. E. Burns, Mr. K. R. von Stieglitz, O. B. E.
Hon Secretary/Treasurer (1959): Mr. W. F. Ellis.

The following members of the Branch Council continued in their term of office for 1959:

Chairman: Mr. G. H. Stancombe.
Vice-Chairman: Dr. C. Craig.
Past Chairman: Mr. Justice G. H. Crawford.
Members of Council: Mr. R. S. Smith, Mr. R. H. Stewart, Mr. John Lord.

During the year under review, Mr. G. H. Stancombe and Mr. W. F. Ellis represented the Northern Branch on the General Council. In addition, Mr. Stancombe served as a member of the Standing Committee of the Society. Mr. Justice G. H. Crawford continued to act as the Northern Branch nominee on the Cradle Mountain-Lake St. Clair National Park Board.

## Activities During 1959.

Eleven General Meetings and one Special Meeting were held at which the following papers were presented:

*General Meetings*:

20th February: "The Eucalypts of Tasmania" by Mr. H. J. King.

20th March: "Some Incidents in the Lives of the Early Judges of Tasmania" by R. W. Baker Esq., B.C.L., B.Litt., Ll.B.

17th April: "The Growth of Tasmania's Shoreline" by Mr. J. L. Davies, M.A.

25th May: "The Application of Waterpower in Tasmania since 1890" by Mr. K. M. Dallas, B.Com.

26th June: "The Essay in Australia", by Prof. L. A. Triebel, M.A., D.Litt.

31st July: "The Development of Australian Postal Services", by Mr. C. F. Perkins and Mr. K. Adams.

28th August: 'The Life and Times of Church and Clergy in the Early Days of the Colony", by Rt. Rev. W. R. Barrett, M.A., Th.D.

28th September: "What's a Biophysicist" by Dr. B. I. H. Scott, B.Sc., Ph.D.

9th October: "The Role of Botanic Gardens and Arboreta in the Community" by Dr. W. S. Stewart, Ph.D.

27th November: "The Stability of Natural Slopes" by Dr. G. D. Aitchison, M.E., Ph.D.

11th December: Members Evening.

(1) "The Significance of Decimal Currency", by Mr. S. V. Tilley, F.C.S., F.A.S.A.
(2) "Majorca" by Miss J. Williams.
(3) "An English and a Swiss Village", by Mr. Gordon Willing.
(4) "The Royal Botanic Gardens, Kew", by Mr. T. E. Burns.
(5) "What happened to the Marsh Mallow" by Mrs. I. J. Mead.
(6) "Some Excursions", by Mr. R. S. Smith.

*Special Meeting*:

1st June: "Early Tasmanian Architecture" by Mr. R. S. Smith, F.R.I.B.A., F.R.I.A.I. (Conducted with members of the School of Architecture of the University of Melbourne).

*Excursions*:

Four excursions were held during the year:
20th February: Lisle Goldfields, led by Mrs. B. J. Edwards.
28th February-2nd March: Cradle Mountain National Park led by Messrs. T. E. Burns and I. Jennings.
19th April: "Kirklands", Campbell Town led by Mr. G. H. Stancombe.
15th November: Old Launceston Waterfront, led by Mrs. I. J. Mead.

The excursion to the Cradle Mountain Reserve was of particular note for it occupied three days during which the thirty-five members who attended were accommodated at the Waldheim Chalet. Geology and botany groups were led by Mr. I. Jennings and Mr. T. E. Burns respectively and an outline of the history of the reserve was given by Major R. E. Smith.

The Branch Council has maintained a close relationship with the General Council during the year and note with pleasure that the General Council held one of its meetings in Launceston.

The transcription of the diaries of John Helder Wedge was completed and, together with supplementary notes, have been submitted for publication in the Papers and Proceedings of the Society.

In conclusion, the Branch Council records with appreciation the services and facilities provided during the year by the Queen Victoria Museum.

G. H. STANCOMBE, Chairman.

W. F. ELLIS, Hon. Secretary.

Papers and Proceedings of the Royal Society of Tasmania, Volume 94

# EROSION SURFACES, RIVER TERRACES, AND RIVER CAPTURE IN THE LAUNCESTON TERTIARY BASIN

By

K. D. Nicolls

C.S.I.R.O. Division of Soils, Hobart.

(With 2 plates and 2 text figures).

## ABSTRACT

An erosion surface probably of Pliocene age, extends throughout the Launceston Tertiary Basin at elevations between 550 and 1050 feet and is here named the Woodstock Surface. It slopes gently eastwards from Deloraine and north-westwards from Tunbridge and is developed across Tertiary sediments, dolerite and basalt. Lateritic podzolic soils are typical of it on the sediments, and lateritic krasnozems with outcrops of laterite (bauxite) on the dolerite and basalt. It is a possible time marker, younger than the basalts at Deloraine-Westbury and at Campbell Town but of uncertain relationship to the basalt at Evandale.

Several gently sloping surfaces can be recognised at levels below the Woodstock. The Cataract Gorge between Hadspen and Launceston separates these surfaces into two unrelated systems, the South Esk system above it and the Tamar system below. The former system comprises the present floodplains (Canola), and the Brumby and Brickendon Terraces, respectively 8 to 18, and 40 to 120 feet above the floodplains. Local base levels for this system are set by the dolerite at the head of the Gorge. The Canola soils are humic gleys; the Brumby meadow podzolics or solods; and the Brickendon lateritic podzolics, distinguished from Woodstock soils by the prevalence of siliceous gravels in them. In places windblown sands are superimposed upon each terrace. Climatic fluctuations, variations in resistance of dolerite to corrasion, and renewed faulting are considered as possible causes of terrace formation. The Brickendon Terraces are younger than the Evandale basalt and are thought to be Pleistocene. Their lateritization is ascribed to interglacial phases. The Tamar system which has not been fully investigated includes terraces at elevations of 300-330 feet and 100-140 feet near Launceston and 130 feet near Georgetown, and a bench at 450 feet in the valley of Rose Rivulet.

Instances of river capture, involving the South Esk River, Liffey River, Brumby Creek and other streams are noted. A reconstruction of the late Cainozoic history of the Basin is attempted.

## INTRODUCTION

Soil surveys in the Launceston Tertiary Basin have shown that the various soils are closely related to geomorphic units, and that maps of soils are in fact also maps of these units. Consequently a study of geomorphology has been made in an attempt to explain the pattern of soils and to throw light on their genesis, because the history of the landscapes is also the history of the soils. The study shows that the floor of the Basin is a stepped landscape, throughout which may be traced a sequence of distinct levels, each with characteristic soils. Soil maps of the Longford and Quamby rectangles are available (Nicolls, 1958*a*, 1959) and this paper is to be read in conjunction with them.

Johnston (1873) to whom the name Launceston Tertiary Basin is due, believed that the Tertiary sediments were deposited in a large lake, and Carey (1946) follows this. However, the nature of the sediments and the absence of remnants of a seaward barrier to the lake raise serious objections to the lake theory. Davies (1959) pictures the whole of this area as one part of a much more extensive "Lower Coastal Surface" developed within and by erosion of a "Higher Coastal Surface" which preceded it. The present paper is not concerned with the correctness or otherwise of either of these views; the history which it attempts to unravel starts, probably towards the end of the Tertiary Period, with the *Woodstock Surface*—a very gently sloping surface occupying the floor of the Launceston Basin between the Ben Lomond Plateau to the north-east and the Central Plateau to the south-west. For the most part the Woodstock Surface was developed in Tertiary sediments, but whether these sediments and been deposited in a lake or as a piedmont plain would appear not to have affected the subsequent developments discussed here.

The term "surface" is used with a more restricted meaning than that of Davies, and corresponds rather with his term "phase". The surfaces described below all represent phases in the later development of Davies' "Lower Coastal Surface". However, in the terminology of Butler (1959) the older of them may include more than one "groundsurface".

Where figures for the elevations of particular points are quoted, they refer to measurements from bench marks based on State Datum.

## OUTLINE OF THE SURFACES AND TERRACES

The Woodstock Surface has been largely removed by erosion, and is now represented by discontinuous remnants, recognisable by their

elevation (550-1050 feet) and by the lateritic soils upon them. The name Woodstock is that given by Stephens et al (1942) to the series of soils they found to be characteristic of these remnants in the neighbourhood of Longford and Cressy. The largest remnant of the Woodstock Surface is traversed by the Midland Highway between Conara and Epping. As a whole the Woodstock Surface slopes gently north-westwards from the vicinity of Tunbridge to the valley of the Tamar River, and eastwards from Deloraine to Hadspen. Though details are obscure, it is clear that the rivers of its time had the same general direction as today, reaching the sea via the Tamar Valley. The surfaces below the Woodstock are recognisable as river terraces related to the streams of the present day. The Cataract Gorge with its head near Hadspen at an elevation of 410 feet, and its foot near sea level at Launceston, separates the river terraces into two unrelated systems. Those upstream from Hadspen, along the South Esk River and its many tributaries, will be referred to as the South Esk system. Those along the Tamar River, the North Esk, and the tributaries of the North Esk will be referred to as the Tamar system. The Tamar system has not been fully studied, and is treated only briefly here.

The terraces of the South Esk system, arranged in order from highest to lowest have been named as follows:—

Brickendon—40 to 120 feet above present floodplains;
Brumby—8 to 18 feet above present floodplains;
Canola—present floodplains, 5 to 10 feet above normal water levels in rivers.

Each terrace appears to have much the same gradient as the present rivers; that is, the ranges in elevation quoted above do not arise from any consistent increase or decrease of height of one terrace above another with distance along the stream. Rather they are due to a combination of two other factors. Firstly, while the distinction between Brickendon as a whole and Brumby as a whole is quite marked, Brickendon appears to represent more than one phase in terrace formation and Brumby may do likewise. Secondly, a section across a terrace perpendicular to a river may be slightly concave or convex rather than exactly horizontal, and the concavities of adjacent terraces may not coincide.

## THE WOODSTOCK SURFACE

The Woodstock Surface is represented on the soil map of the Longford rectangle (Nicolls, 1958*a*), by the soils of the Woodstock Association together with certain of the small scattered occurrences of lateritic soils within the Eastfield, Breadalbane and Relbia Associations. The Woodstock and Relbia soil associations are on Tertiary sediments, the Eastfield on dolerite, and the Breadalbane on basalt. On the soil map of the Quamby rectangle (Nicolls, 1959) the Woodstock surface is represented by the Woodstock Association and by the lateritic krasnozems developed fairly extensively on basalt and locally on dolerite. South of the Longford rectangle soils of the Woodstock Association extend from Epping to Conara and are found in the valley of the Isis River and near Blackmans River four miles west of Tunbridge. Around Campbell Town several basalt hills are capped at the same level by outcrops of laterite or by lateritic krasnozem soils. These scattered remnants at comparable levels strongly suggest a surface, or perhaps a combination of two surfaces as discussed below, once continuous over the whole floor of the Basin, an area of some 1300 square miles.

Owen (1954) and Edwards (1955), reviewing outcrops of laterite and bauxite throughout Tasmania and elsewhere as potential sources of aluminium ore, considered several in the Launceston Basin. Those they described under the headings of Fordon, Epping, Campbell Town and Conara all belong to the Woodstock Surface and those designated Westbury, Lake River, and White Hills may also belong to it. Though Owen (loc cit, p. 199) accepted peneplanation elsewhere as accounting for the existence of laterite he discounted it in Tasmania, believing that laterite here is restricted to basalt and dolerite. However, the Woodstock Surface is either a peneplain or some other form of gently sloping erosional surface, and it is clear that the lateritic soils of the Woodstock Association on Tertiary sediments are the counterpart of the laterite occurring at the same levels on basalt and dolerite.

The Woodstock Surface may be divided into a higher and a lower part, called in this paper Woodstock A and Woodstock B respectively. Where both are present in the one locality, as in Fig. 1 (see page 4) and near Longford and Perth, Woodstock A stands about 200 ft. higher than Woodstock B.

Two views of this are possible. Firstly, the two levels may be separated considerably in time, Woodstock B having developed at the lower level after a period of erosion of Woodstock A. Secondly, the two may be contemporaneous, Woodstock A developing on benches of hard rocks such as the tops of dolerite sills or of basalt flows, while Woodstock B developed at a lower level, mainly on the softer Tertiary sediments. The first view would be more in keeping with the development of the younger surfaces to be discussed below, but the second cannot be dismissed on the evidence available so far. If there could be found close together, remnants at the two levels, developed in the softer sediments away from the influence of dolerite and basalt, the question would be resolved in favour of the first alternative, but such evidence is lacking. On the first view, the name Woodstock would be better reserved for Woodstock B, and a different name found for Woodstock A. However, in areas where the two levels are not represented together as for instance west of Westbury, there is difficulty in deciding between them, and it seems better to use the single name Woodstock and to designate A or B wherev.er possible.

**Woodstock A.** There are only isolated small remnants at this level. The soil map of the Longford rectangle shows a prominent bench in the dolerite forming the eastern wall of the Basin, running right across the sheet, parallel to and about six miles east of the course of the South Esk River. It is two to three miles wide and at a general elevation of 800-900 feet. Its top consists mainly of low rolling dolerite hills, with non-lateritic and presumably relatively young soils of

the Eastfield Association on their slopes. However at scattered points on the flatter hilltops and shoulders there are lateritic soils and some exposures of massive laterite, which appear to be the remnants of a formerly continuous surface. Those associated with dolerite or basalt are marked on the soil map with a red stippling. One of them is represented in Figure 1 (see page 4). Owen (loc cit) refers to three others, the laterite at "Fordon", and the lateritic krasnozem soils at Vineys Sugar Loaf and another small basalt hill on the Blessington road three miles east of White Hills. The soil map also shows several small areas of soils of the Woodstock Association on this bench. The bench continues northwards into the Launceston rectangle, and krasnozem soils on dolerite near Turners Marsh at about 800 feet elevation may be correlated with it. Lateritic soils occur at about the same elevation at scattered points on the dolerite hills around Mt. Arnon a few miles north of Perth.

Between Deloraine and Westbury there are several small exposures of laterite on the tops of the basalt hills, at elevations around 1000 feet (Plate 1 (*a*). These exposures closely resemble the "hard ferruginous posolitic bauxite" (Edwards, 1955) on basalt near Campbell Town. On the flatter hilltops appreciable areas of lateritic krasnozem soils surround these outcrops, as shown on the soil map of the Quamby rectangle. The elevations of the laterite exposures are consistent with a surface having a slope of about 18 feet per mile to the east. However it is a matter for conjecture whether such a surface would be accordant with Woodstock A or with Woodstock B in the neighbourhood of Longford and Perth. Tentatively, these western occurrences of laterite may be assigned to Woodstock A. Two miles south and south-east of Westbury, there is a suggestion of the presence of both surfaces on the basalt hills, A at about 900 feet and B at about 750 feet above sea level.

**Woodstock B.** The general elevation of Woodstock B falls from 700-750 feet near Campbell Town to 550-600 feet near Longford and Carrick. In places this surface may be remarkably flat over extents of one or two hundred acres, but commonly it is gently undulating with a relief of about 50 feet. Much larger remnants of Woodstock B exist than of Woodstock A, for instance that which the Midland Highway crosses between Conara and Epping. Most of the areas of soils of the Woodstock Association shown on the soil maps belong to this level. They are on the Tertiary sediments, but Woodstock B like Woodstock A may also cross dolerite and basalt. Where it does so, the soils are usually lateritic krasnozems, and outcrops of laterite may occur.

Woodstock B is well represented on basalt around Campbell Town by the several outcrops of laterite to which Owen and Edwards (loc cit) refer. A prominent example of a laterite pavement on dolerite on this surface may be seen 500 yards south-east of the Illawarra Church between Longford and Carrick.

## THE SOUTH ESK SYSTEM OF TERRRACES

Figure 1 is a measured section across the South Esk valley near Clarendon, drawn to scale with vertical exaggeration. On the western side of the river the section shows typical development of Brickendon, Brumby and Canola surfaces. There are distinct levels in the Brickendon, at 90 and 60 feet above the floodplain; the flat Brumby terrace stands 12 feet above the floodplain, and sharp banks mark the limits of each. A knoll on the floodplain at the water's edge on this side accentuates the apparent entrenchment of the river. East of the river these three formations are not so typical in this secton, because on this side it traverses the valley of a tributary stream. Further east, remnants of both Woodstock B and Woodstock A are represented. Knolls of windblown sand rise above the floodplain east of the river.

**Brickendon Terraces.**—The name Brickendon is tht given by Stephens et al (1942) to the series of soils they found to be characteristic of these terraces in the neighbourhood of Longford. The Brickendon Terraces are very extensive, occupying 70 square miles of the Basin floor within the Longford rectangle alone. However, this large area of the Brickendon Terraces is partly a reflection of their complexity noted above. About the confluence of the South Esk and Lake Rivers, the Brickendon Terrace must have had at one time an uninterrupted width of some 10 miles. The Midland Highway traverses a Brickendon terrace almost continuously for 16 miles between Epping and Perth, while the Bass Highway crosses another for three miles from Carrick westwards.

The range in height of the Brickendon Terraces, 40 to 120 feet above adjacent floodplains, has already been mentioned. The higher level in Figure 1, and the extensive plain between Longford and Perth at approximately the same height above the river, are examples of the upper end of the range. The lower level in Figure 1, and the terrace west of Carrick, 50 to 70 feet above adjacent floodplains, illustrate the lower end.

Boundaries of the Brickendon Terraces with the Brumby are almost always marked by steep banks, as in Figure 1. Occasionally where the lower Brickendon terraces abut the Woodstock Surface, boundaries are similarly marked by relatively steep slopes, as for example across the Midland Highway one mile north of Epping. There the Brickendon Terrace appears to be a continuation of the 60 foot level in Figure 1, and the Woodstock Surface stands 40 to 50 feet higher. The higher Brickendon terraces stand only slightly below the general level of the Woodstock Surface in their locality, and meet it in gentle slopes. The lower Brickendon terraces may also meet the Woodstock Surface in gentle slopes, and in such situations the recognition of boundaries depends mainly upon the presence of the siliceous gravels characteristic of the Brickendon. Small pebbles of quartz do occur on the Woodstock Surface, but they are rare, whereas on the Brickendon Terraces siliceous gravels are normally a major component of the deposits.

Cuttings and bores on the Brickendon Terraces reveal that the siliceous gravels are generally present to depths of at least 12 feet, variously stratified with sands and clays. In the railway cutting one mile east of Longford Station gravelly deposits overlie basalt at a depth of 30 feet below the top of the terrace. Near Longford Station is

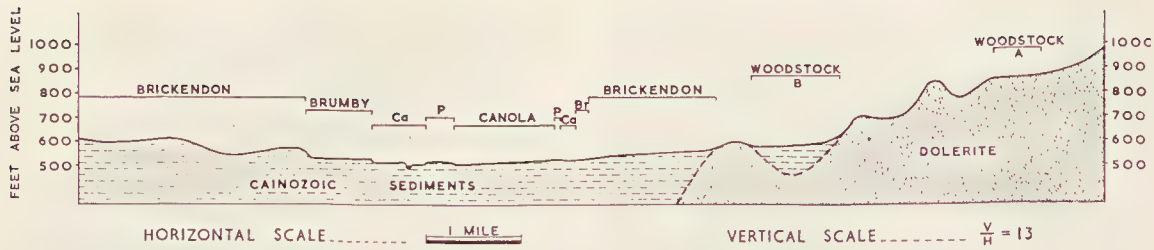


FIGURE 1.—Section across South Esk Valley near Clarendon. To the left (west) of the river there are two distinct steps in the Brickendon, and the Brumby terrace is well developed. To the right (east) of the river the section traverses the valley of a tributary, with development of Canola at the expense of Brumby and with bevelling of Brickendon. Small knolls of windblown sands (P) rise above the floodplain on the eastern side of the valley. Abbreviations: Ca, Canola; Br, Brumby; P, Panshanger.

another cutting exposing the siliceous gravels on a level 50 feet below their base in the first cutting, though this evidence by itself hardly justifies a conclusion of a total depth of 80 feet of gravelly deposits in this locality. Three miles east-north-east of Cressy there is a bluff at the edge of an extensive Brickendon terrace, standing 70 feet high above a sharp bend in the Lake River. The section is largely obscured by debris, but the gravels do not extend more than 20 feet below its top; probably their depth is appreciably less. The sediments below are without gravels except in debris at the bottom of the section, and are interpreted as Tertiary (pre-Evandale basalt).

The Brickendon gravels are strongly water-worn, some times faceted, and vary from one quarter to three inches in diameter with occasional ones up to six inches. The great majority are quartz or quartzite. Waterworn fragments of silicified wood are common, as noted by Johnston (1873) and by Carey (1946). In places there are occasional pieces of sandstone, and of hardened mudstone with Permian fossils. The quartz or quartzite gravels are believed to be the glacial erratics and other pebbles weathered from the Permian rocks of the river catchments. Alluvial fans at the base of the Western Tiers near Meander are strewn with such pebbles from the adjoining Permian strata. Except in the immediate neighbourhood of outcrops, pebbles of dolerite and basalt are either absent from or at least very rare in the Brickendon gravels. This is a remarkable feature particularly in view of the prevalence of dolerite in all of the river catchments. Lateritization of the Brickendon Terraces would account for their absence by weathering from the surface of the terraces, but at depth traces of weathered pebbles might be expected to remain. The Brickendon Terrace near Bracknell (Fig. 2, page 9), crosses a low ridge of dolerite. Typical soils occur there, but with frequent boulders of dolerite among them.

**Brumby Terraces.**—The name Brumby is taken from the type locality in the valley of Brumby Creek south of Cressy, though other streams have developed more extensive terraces at corresponding levels. Where the Nile River joins the South Esk the Brumby Terrace is five miles wide. A good view of this extensive terrace can be seen to the east from the Midland Highway three miles north of Powranna. Meandering streams have cut into the Brumby Terraces and have established the Canola Floodplains at the next lower level, but apart from this the low relief of the Brumby Terraces has protected them very largely from erosion. They are flat, with little bevelling and generally join the Canola Floodplains in sharp banks (Fig. 1, Plate 2). Most observations of the height of Brumby above Canola fall within the narrow range 10 to 12 feet. However there is occasional evidence of small areas of subsidiary terraces at levels a few feet higher or lower. Unusually high floods reach Brumby level.

Borings and the few cuttings in the Brumby Terraces show stratification with sandy clays, sands and gravels to depths of at least eight feet, but whether this represents the filling of valleys through the Brickendon or the re-working of Brickendon and earlier Tertiary deposits by river planation is not known. In general, dolerite is absent from the gravels of the Brumby Terraces as it is from the Brickendon, but in some places, as near the confluence of the South Esk and Nile Rivers dolerite pebbles are abundant. On the soil maps, such areas with dolerite gravels at the level of the Brumby Terraces have been distinguished from those without. Most of the floor of the long trough between the McRaes Hills ridge and the foothills of the Tiers has been regarded as Brumby Terrace, but its origin may be somewhat atypical, since Permian rocks underlie it at shallow depth (G. E. A. Hale, personal communication).

**Intermediate terraces.**—In the valleys of the Liffey River, Whitemore Creek, and a tributary of the latter, terraces have been found at heights of 20 to 30 feet above adjoining floodplains as for example one mile north of Bishopsbourne. Their soils most resemble the Brumby, but have features also of Brickendon. Since corresponding intermediate terraces have not been observed in other valleys it would appear that these may be the result of some conditions peculiar to tributaries of the Meander River.

**Canola Floodplains.**—These vary in development from intermittent narrow strips on one side of a stream, to extensive flats broken by numerous abandoned channels, as along the South Esk River east of Powranna where they reach widths of one and a half miles. Various stratification of clays, sands and gravels may be seen in the banks of rivers and small creeks, and borings along Brumby Creek have shown similar stratification continuing below the level of the creek bed. That there has

been some recent filling of the floodplains is shown by the partial burial of dunes of the windblown sands described in the next section. However the strata beneath stream channel level may belong to earlier phases.

**Windblown sands.**—The soil maps show discontinuous deposits of sand (Panshanger Association) along the eastern sides of most valleys in the Launceston Basin. Such deposits are common throughout east-central Tasmania (Nicolls, 1958*b*). Varying proportions of clay have accompanied these sands, presumably moving as aggregates of the same dimensions as the sand grains. In the Launceston Basin the great majority of the deposits are very low in clay, though there are also some high in clay. From the distribution and stratigraphy of these deposits it is evident that they have been moved from the valley floors by prevailing westerly winds. They overlie all formations above the Canola, including the slopes and tops of terraces, and hillsides of dolerite and basalt. Knolls of the sands also occur on the floodplains but there the relationship is different. Along Brumby Creek the sands have been found by boring to extend several feet below floodplain level and to be partially buried by finer textured sediments. The sands then are younger than the Brumby Terrace, but older than the present phase of the Canola. The aeolian origin of these sands has not always been recognised. Thus Nye (1926) and Edwards (1939) mistook them for waterlaid sediments where they overlie basalt between Campbell Town and Conara. Stephens et al (1942), while recognising the aeolian origin of lunettes around lagoons on the Woodstock Surface, referred to soils on the windblown deposits on the valley floors as "Alluvial Soils Type A".

## THE TAMAR SYSTEM OF TERRACES

A prominent bench at elevations of 300-330 feet runs from the vicinity of Relbia to the Carr Villa Cemetery. It has lateritic soils containing siliceous gravels and closely resembling those of the Brickendon Terrace. Further work is necessary before this bench can be satisfactorily correlated with other remnants, but it seems likely that it may have been formerly continuous with a terrace standing about 130 feet above the river between Bell Bay and George Town, which also has lateritic soils. The slope between is approximately the same as that of the Woodstock Surface between Campbell Town and Longford, though at lower levels. Soils closely resembling the Woodstock series, with outcrops of laterite, occur at 150-200 feet elevation two miles north-east of George Town, and these too may be related.

Carey (1946) noted the well developed terraces on both sides of the North Esk River near St. Leonards. They stand at elevations of about 140 feet, and probably correlate with another prominent terrace about 100 feet above sea level at Mowbray. They have not been traced further downstream in the present study, nor have their soils been examined. Green (1959) reports erosion surfaces and terraces near Beaconsfield, some of them with characteristic siliceous gravels. Further study is required to relate these to the valley as a whole.

Around the steep sided valleys of Rose Rivulet and its tributaries, a series of flat-topped spurs forms a discontinuous bench at about 450 feet elevation. This is too high to relate to the 300-330 foot terrace only four miles downstream. Moreover its soils resemble those of the Brumby Terraces, indicating comparative youth. It stands upstream from a bar of basalt on either side of Rose Rivulet three miles north of Evandale. Before it was breached, this bar may have perched a local base level at 400-450 feet, in a manner similar to that of the dolerite in the Cataract Gorge.

## SOILS

Butler (1959) has recently pointed out that in landscapes which have had a history of cycles of erosion and/or deposition, there are "persistent zones" which having formed in one cycle escape removal or burial in later cycles. In these zones soil profiles continue to develop through two or more cycles virtually unaffected by either accession or physical removal of soil material. In the Launceston Basin, with the exception of gullies or shoulders locally eroding in the present cycle, areas shown on the soil maps as Woodstock, Brickendon and Brumby Associations represent such persistent zones.

Remnants of the Brumby Terraces are flat and have been bevelled by erosion, or covered by windblown deposits, only locally. On the flat surfaces, soil profiles must be of the same age as the terraces themselves. These soils have continued to develop beyond the influence of the erosison due to the subsequent phases of lowering of base level and formation of the Canola Floodplains. Soils of the Brickendon Association are still older. They extend down gentle slopes as well as over the flat tops of the Brickendon Terrace remnants and it is suggested that the erosion which produced these slopes took place early in the history of the Brickendon Terraces. These slopes have been affected little if at all by later cycles of erosion—that is, they are part of an early groundsurface (Butler, 1959) which existed before the formation of the Brumby Terraces and has persisted in these places since. The case of the Woodstock soils is less clear, and it cannot be established that they were unaffected by the early phases of erosion of the Brickendon Terraces. However they are at least as old as the soils of the Brickendon Association; some if not all of them are considerably older. The differences between these associations of soils reflect both the total passage of time, and the differing climatic conditions to which the older and higher surfaces may have been exposed before the younger ones were formd. In addition, they are partly due to differences in the nature of the terrace deposits, particularly the prevalence of siliceous pebbles on the Brickendon Terraces.

The Woodstock soils where developed on Tertiary sediments are lateritic podzolics (Stephens, 1956) with friable, brightly coloured clays overlain by sandy A horizons containing ferruginous pisolites and sometimes pieces of laterite, or aggregations of the ferruginous nodules, up to a foot or occasionally more in diameter. Where the Woodstock Surface crosses dolerite or basalt which supplies more iron on weathering, the soils are generally lateritic krasnozems (Stephens, 1956). These are red-brown very friable clays with little contrast of texture

down the profile, and containing irregular pieces of semi-hard laterite or bauxite. Occasionally amongst the lateritic krasnozems may be found small outcrops or pavements of laterite, in boulders up to four feet deep.

The Brickendon soils are lateritic podzolics like the Woodstock on Tertiary sediments, with similar friable though sometimes rather duller coloured clay B horizons. They differ from the Woodstock in that most profiles contain large quantities of the siliceous gravels, concentrated with the ferruginous nodules in the sandy A horizons. Where, as occasionally happens, the siliceous gravels are missing from the profile, other profiles within a short distance on the same level will be found to contain them. Where pieces or boulders of laterite occur on the Brickendon Terraces, they are usually studded with the siliceous gravels.

The soils of the Brumby Terraces are not lateritic, either because the climatic conditions to which they have been exposed have been unfavourable, or because they are too young. In the classification of Stephens (1956) these soils may be placed as meadow podzolics or as solods. They have grey sandy A horizons usually with a strongly bleached $A_2$, and with a sharp contrast of texture to a clay B horizon. The clay lacks the bright colours of the Woodstock and Brickendon, is tough or plastic, rather than friable, and sometimes shows columnar structure. Below, there is sometimes a little carbonate. Ferruginous nodules or siliceous gravels may occur throughout the profile.

The Canola Floodplains are characterised by humic gley soils—dark coloured, organic clay loams or clays overlying mottled dark grey and yellow plastic clays which are usually wet.

Table 1 summarises the main features of these characteristic soil profiles by which, together with their topographic positions, the Woodstock Surface and the terraces of the South Esk system may be recognised.

[*For Table I, see facing page.*]

Parts of the former Woodstock Surface and of the Brickendon Terraces have suffered extensive erosion at some period or periods subsequent to the formation of soils of the Woodstock and Brickendon Associations. These eroded parts have distinct soils, shown on the soil maps as Cressy and Newham Associations. The Cressy soils are mainly on eroded parts of the Woodstock Surface, but particularly west of the Liffey River they are also developed upon eroded Brickendon terraces. Their genesis by truncation of Woodstock soils is discussed by Stephens et al (1942). They are virtually restricted to the portion of the area west of the Lake River. The Newham soils are found on eroded Brickendon terraces to the east of the Lake River. Remnants of the Woodstock Surface in that portion of the area have not been eroded in the same way as have their counterparts to the west. The reason for this zoning of the Cressy and Newham Associations is obscure, but may relate to erosion at different periods, or to the slightly wetter climate of the western part of the area, or to both these factors.

A full account of the soils of the area is being published elsewhere.

## RELATIONSHIP OF THE WOODSTOCK SURFACE AND THE BRICKENDON TERRACES TO THE BASALT AT EVANDALE

The basalt overlies the early Tertiary sediments and is therefore younger than them. The lowest elevation at which basalt outcrops in this district is 275 feet above sea level at "Talisker", three miles north of Evandale. There are some indications that this may represent a point of eruption, but even if so, basalt rests on the Tertiary sediments at several points in the vicinity at elevations not much higher. This accords with Carey's (1946) view that before extrusion of the basalt the South Esk River or its predecessor flowed northwards past Evandale. This seems a more likely course than the Cataract Gorge for the waters of the Lake and the Meander Rivers as well as of the South Esk at this time. According to Carey, the outpouring of basalt near Evandale blocked this path and turned the South Esk River along its present course westwards to enter the Cataract Gorge at Hadspen. Subsequently "extensive deposits of post-basalt gravels . . . over 100 feet thick near Longford" accumulated because of the damming of the river. This may be taken as a reference to the Brickendon Terrace.

At several points along the bank of the Soutn Esk River near Evandale, at Perth, and just over one mile east of the confluence of the South Esk and Lake Rivers, basalt outcrops at water level at the foot of the Brickendon Terraces. In the deep railway cutting east of Longford 30 feet below the local level of the top of the Brickendon terrace, basalt is exposed with the siliceous gravels resting upon it. It seems reasonable to assume that these exposures of basalt are linked with the main body of basalt at Evandale and represent an old valley filling since buried by the Brickendon Terraces. Moreover the pattern of Brickendon Terraces disclosed by the soil map and their slope between Evandale and Hadspen strongly suggest that during their formation the South Esk River flowed, as it does now, westwards from Evandale to Longford. The Brickendon Terraces then, are younger than the basalt, though how much younger is not clear.

One mile north of Evandale, the Brickendon gravels, at an elevation just over 550 feet, are on the divide between the South Esk and North Esk drainage. It is therefore conceivable that for some time after the basalt eruption, during or after the establishment of the highest Brickendon Terraces, the river found a course northward across the basalt. This might explain the flatness of the basalt sheet at this elevation around Western Junction. However it seems unlikely that the river having established such a course would abandon it for the apparently more difficult one via the Cataract Gorge. The obviously imminent capture of the South Esk River by the North Esk near Evandale (Nye and Blake, 1938; Carey, 1946) is in fact in the reverse direction.

The relationship of the basalt at Evandale to the Woodstock Surface is uncertain. The laterite and lateritic krasnozem soils capping basalt hills in the Deloraine-Westbury district around 1000 feet elevation are interpreted as remnants of the Woodstock Surface developed on basalt; that is, the

## TABLE I.

### Typical Soil Profiles.

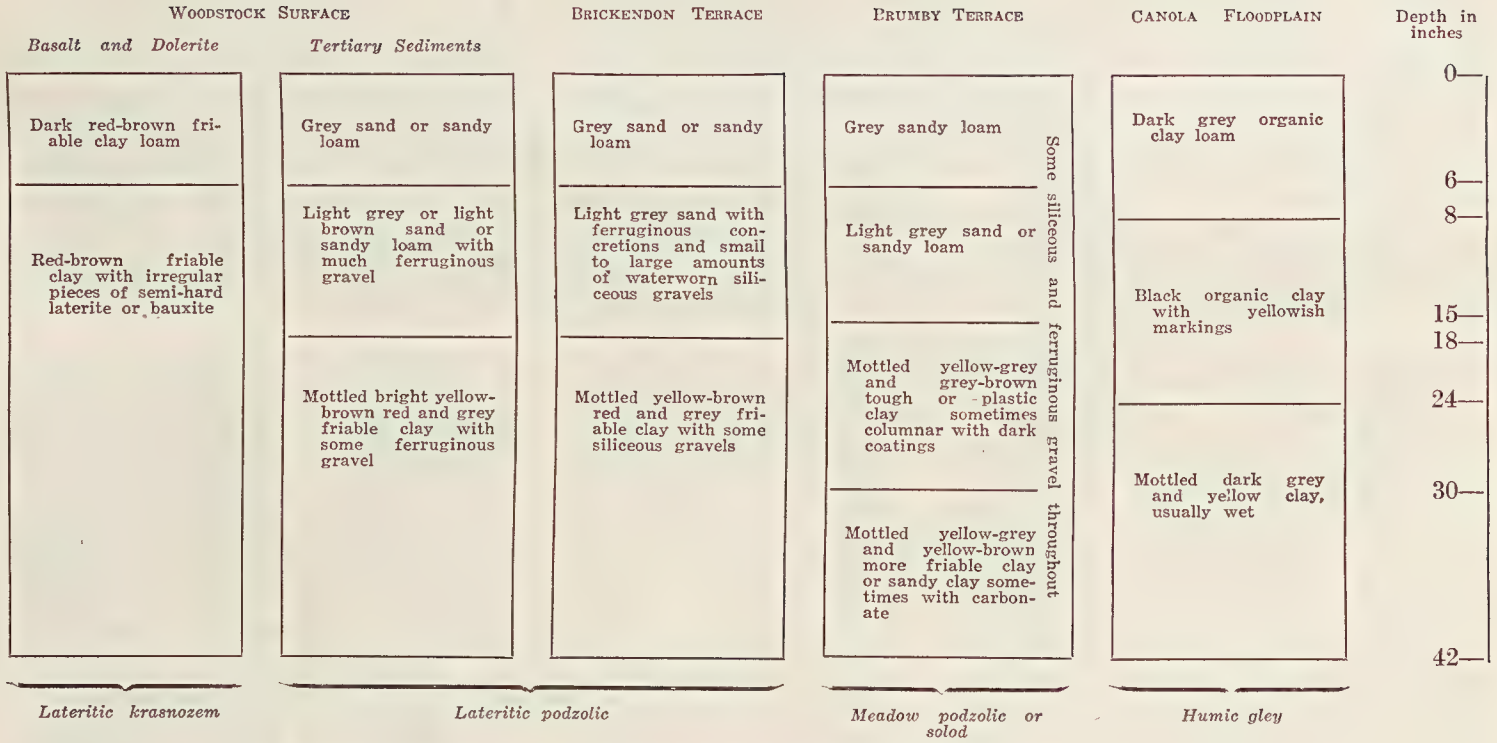
Woodstock Surface
Basalt and Dolerite
Tertiary Sediments
Brickendon Terrace
Erumby Terrace
Canola Floodplain
Depth in inches
Dark red-brown friable clay loam
Red-brown friable clay with irregular pieces of semi-hard laterite or bauxite
Grey sand or sandy loam
Light grey or light brown sand or sandy loam with much ferruginous gravel
Mottled bright yellow-brown red and grey friable clay with some ferruginous gravel
Grey sand or sandy loam
Light grey sand with ferruginous concretions and small to large amounts of waterworn siliceous gravels
Mottled yellow-brown red and grey friable clay with some siliceous gravels
Grey sandy loam
Light grey sand or sandy loam
Mottled yellow-grey and grey-brown tough or plastic clay sometimes columnar with dark coatings
Mottled yellow-grey and yellow-brown more friable clay or sandy clay sometimes with carbonate
Some siliceous and ferruginous gravel throughout
Dark grey organic clay loam
Black organic clay with yellowish markings
Mottled dark grey and yellow clay, usually wet
0
6
8
15
18
24
30
42
Lateritic krasnozem
Lateritic podzolic
Meadow podzolic or solod
Humic gley

TABLE 1.—Simplified descriptions of soil profiles typical of the Woodstock Surface and of the South Esk system of terraces. Boulders of laterite may be associated with the Woodstock and Brickendon profiles.

basalt there predates the Woodstock Surface. At Campbell Town, laterite and lateritic soils occur on basait at several points and Edwards (1955) has shown that this laterite has in fact been derived from basalt or from basaltic tuff. These occurrences are at the local elevation of the Woodstock B surface (700-750 feet) so that the basalt there too appears to be pre-Woodstock. Similarly, lateritic krasnozem soils overlie basalt at Vineys Sugar Loaf near "Fordon" at the elevation of the Woodstock A surface. Around Evandale the only occurrence definitely associated with basalt which may be ascribed to the Woodstock Surface is at the Woodstock A level on a small hill on the Blessinton road five miles north-east of Evandale township. This hill, which is mentioned by Owen (1954), is capped at elevations from 900 to 990 feet with lateritic krasnozem soils containing boulders of basalt and pieces of laterite or bauxite. Laterite boulders and similar soils occur in small areas on two other hilltops, one just over 700 feet elevation four miles east of Evandale and the other at 790 feet elevation three and a half miles north-north-east of Evandale. In each case basalt occurs within a short distance at lower elevation but direct evidence that basalt underlies the laterite is lacking.

On the evidence available so far, the two possibilities therefore remain (*a*) that the Evandale basalt is older and the Woodstock Surface developed upon it and was subsequently almost entirely removed by erosion, or (*b*) that the basalt is younger and filled a valley that had been cut deeply into the Woodstock Surface. If (*a*) is correct it would mean that the formation of the Brickendon Terraces could not have followed immediately upon the blocking of the valley by the basalt, which Carey (1946) implies. On the other hand if (*b*) is correct the basalt eruption at Evandale could be regarded as having initiated the formation of the Brickendon Terraces. Further, if the basalt at Evandale is younger than the Woodstock Surface it is also appreciably younger than the basalts at Deloraine and at Campbell Town and Viney's Sugar Loaf.

The existence of basalts between Evandale and Longford, buried by the Brickendon Terrace raises the question of the possibility of a similar buried connection between the basalt at Evandale and that astride the South Esk River opposite Epping. However the petrological evidence of Edwards (1949, p. 98) makes such a connection doubtful.

## RIVER CAPTURE

Two factors combine to make the Launceston Basin particularly prone to river captures. Firstly there is the alternation of bars of hard rock—chiefly dolerite—with areas of the soft unconsolidated Cainozoic sediments. Secondly, the interfluves often consist entirely of the soft sediments. A stream downcutting in soft sediments may become superimposed upon an underlying body of dolerite, which retards the further progress of corrasion. Meanwhile a more fortunate neighbouring stream, in a course which happens not to be underlain at comparable depth by hard rock, relatively quickly deepens its valley. Unless the interfluve is particularly resistant to erosion, the stage is set for the capture of the first stream by the second.

The impending capture of the South Esk River by tributaries of the North Esk near Evandale is a spectacular example which has been noted by previous authors (Nye and Blake, 1938; Carey, 1946). In the capture area, the South Esk River, perched by the dolerite bar across its path at Hadspen, is 480 feet above sea level. Only two and a half miles away Rose Rivulet, a tributary of the North Esk River, is at 150 feet. At its lowest point (co-ordinates E 513050, N 881450) the divide, consisting of a thin basalt capping over the Tertiary clays and sands, stands 540 feet above sea level, only 60 feet above low water level in the South Esk. A tributary of Rose Rivulet with a steep valley has almost breached the divide by erosion of the relatively unconsolidated sediments and undercutting of the basalt. However the possibility of capture during a flood seems more remote than is suggested by the authors quoted above; the record flood of April, 1929, according to local monuments, could not have been less than 20 feet below the divide.

The soil maps reveal several captures among the group of streams descending the Western Tiers between the Lake River in the south-east and Quamby Brook in the north-west. The "rock bar" factor with all of these is the long low ridge of dolerite running parallel to the Tiers escarpment along the Tiers Fault (McKellar, 1957). The McRaes Hills are part of this ridge, and the township of Bracknell stands upon it. The streams have graded courses across or along the trough between the Tiers escarpment and this ridge. The Lake River has been able to skirt the south-eastern end of the ridge, but the other streams cross it through small gorges. The more rapid cutting of one gorge than of its neighbour has led to the diversion of streams along the southern face of the ridge and the abandoning of some of the gorges. The best examples are an unnamed valley extending from Western Lagoon to Longford, and the valley of Whitemore Creek.

**Western Lagoon—Longford Valley.**—This has clearly been beheaded by the present Brumby Creek drainage system. Western Lagoon now drains into Brumby Creek, with a fall of 29 feet over the short distance from the south-western end of the lagoon to water level in the creek. Beyond the small gap through the dolerite at the north-eastern end of the lagoon, the valley is well defined with a clear fall towards Longford.

Western Lagoon itself occupies a hollow in the McRaes Hills ridge. The presence there of outcrops of sandstone suggests that, as commonly happens in Tasmania, the hollow has been formed by the removal of sandstone by differential erosion, leaving the harder rim of dolerite. The passage through it of the former headwaters of Brumby Creek accounts for this erosion; and swampy conditions on the divide following capture, aided by movement of windblown sands, account for the development of the lagoon.

This capture must be relatively recent—during the Canola phase. It is since the development of Brumby Terraces because a Brumby terrace is

well developed between Western Lagoon and Longford. The existence of windblown sands in the valley suggests that it may have carried a large stream in the main period of sand movement, which is subsequent to the Brumby Terrace phase. Finally, the lagoon on the divide could survive for only a limited period after the capture. Whether a large stream occupied this valley much earlier during the formation of Brickendon Terraces is uncertain. The Brickendon Terrace on the Longford-Cressy highway, three miles from Longford may be ascribed to the Lake River, and possible remnants of a Brickendon terrace between there and Western Lagoon are inconclusive.

**Whitemore Creek.**—Figure 2, prepared from the soil map shows the stream pattern in the neighbourhood of Bracknell. Whitemore Creek appears to be a former course of the Liffey River, and in fact in times of flood some of the water from the Liffey still goes this way. From water level at point A on the Liffey River (Figure 2) only the low river bank interrupts a continuous fall of 38 feet across the terrace to point B at the head of the Whitemore valley. Local residents have taken advantage of this to lead water into Whitemore Creek from a tributary of the Liffey.

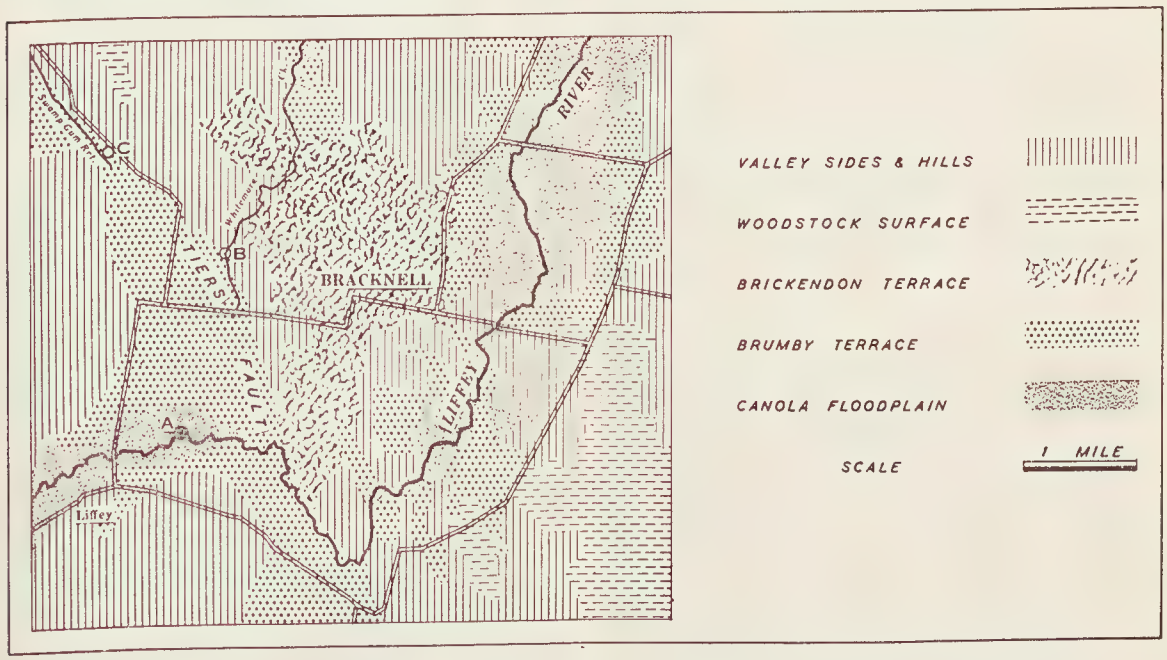


FIGURE 2.—River capture near Bracknell. Whitemore Creek and probably also Swamp Gum Rivulet are former courses of the Liffey River. "Valley sides and hills" includes dolerite, Permian sediments, basalt, and also bevelled remnants of the Woodstock Surface and of the Brickendon Terrace.

It is clear from the pattern of Brickendon Terraces shown by the soil map that during the time of their formation a large stream took the Whitemore course. At Bracknell the Brickendon terrace could be ascribed either to the Whitemore valley or to the present Liffey valley. At Carrick the Brickendon terrace belongs to the Meander River. Between Bracknell and Carrick, no remnants of a Brickendon terrace have been found along the present Liffey course, whereas along the parallel Whitemore valley, there is a prominent and almost continuous Brickendon terrace. Not only could such a large terrace hardly be ascribed to a stream of the size of the present Whitemore Creek, but also below the point B (Figure 2) there is no source of the characteristic siliceous gravels. Both the Whitemore valley and the present Liffey valley below Bracknell have well developed Brumby Terraces at the usual height (10 to 12 feet) above their Canola Floodplains (Plate 2).

The Liffey River may have changed courses several times between these alternative valleys below Bracknell. The existence of a second dolerite bar across the present course of the Liffey near Carrick, which presumably accounts for the unusually large Canola floodplain above it, might tip the balance again in favour of the Whitemore valley at some future time.

**Other Captures.**—The valley of Swamp Gum Rivulet is another likely former course of the Liffey River, since point C (Figure 2) on the crest of the low divide, is slightly below water level at point A on the Liffey. The stream crossing the Bass Highway near Hagley may have lost to the Swamp Gum valley its former headwaters on Cluan Tier. The flat floored valley between dolerite hills immediately to the south-east of Western Lagoon is suggestive of the former passage through it of a stream of moderate size.

## DISCUSSION

### 1. The control of base level.

The terraces of the Tamar system appear to have graded to sea levels at former shorelines some distance down the Tamar Valley or in Bass Strait. Changing sea levels would then account for their present elevations, but until the former shorelines can be located it is not possible to estimate the magnitude of those changes. It may be assumed that since the Woodstock Surface can be traced northward from Launceston, it too graded to a former sea level.

On the other hand, the soil maps show that the terraces of the South Esk system head into the Cataract Gorge near Hadspen, where the river bed is now at an elevation of 410 feet. For these terraces to have been controlled by sea levels would require the sea at such heights that the terraces would grade to them through the head of the Gorge. In the absence of surveys of the area to the north of the Gorge this possibility must be kept in mind; however reconnaissance so far has not revealed a northward continuation of the terrace system. The much more likely alternative is that local base levels for the terraces of the South Esk system have been controlled, independently of sea level, by the dolerite at the head of the Cataract Gorge. (Plate 1 (*b*)).

A more or less regular rate of corrasion of the dolerite gorge would result in a steadily falling local base level for the basin upstream. Terraces may be formed in such conditions (Cotton, 1945, p. 244) but they are in flights, unmatched across the valley. In the Launceston Basin there are some instances of unmatched terraces, and it is possible that varying levels among the Brickendon Terraces may be accounted for in this way. However matched Brickendon Terraces also occur, and the well preserved Brumby Terraces are certainly matched in height across valleys. Relatively rapid changes of base level are required to explain these occurrences.

The alternation of periods of stillstand and terrace formation, with periods of rapid change of local base level might be explained by:—

(*a*) Climatic fluctuations varying the volume of water and the load of sediment carried by rivers.

(*b*) Variations in the resistance of the dolerite bar to corrasion, associated with joint systems in the dolerite.

(*c*) Intermittent movements of a fault system.

Consideration of these possible causes involves the further question of the extent to which the terraces are built by deposition, or are cut in earlier sediments. Unfortunately the few deep sections exposed in the area, and such records of deep borings as are available do not resolve this question. All the terraces are depositional in the surface few feet, since even a cut terrace (strath) has a surface skin of transported material. Borings for the examination of soil profiles, and shallow cuttings reveal stratification, with lenses of river gravels, to depths of eight feet or sometimes more on each terrace. As discussed above the Brickendon Terraces are depositional between Evandale and Longford, where sandy clays and siliceous gravels have buried basalt to depths of at least 30 feet. This deposition in the vicinity of the basalt blockage, does not necessarily preclude the Brickendon Terraces being cut in earlier sediments further upstream, and such appears to be the case with the bluff on the Lake River near Cressy. The sediments exposed on its face are considered to be pre-Brickendon. However this is an isolated section, and may or may not be typical of the terrace in its locality. If, as seems likely, the Brickendon Terraces consist mostly of gravelly deposits resting disconformably upon non-gravelly earlier sediments, the depth of the former will naturally vary with the pre-Brickendon topography, and in places only a skin of the later transported material will cover the older sediments. The sharp banks between Canola and Brumby, between Brumby and Brickendon, and occasionally between Canola and Brickendon, are strongly suggestive of river planation (Figure 1; Plate 2). Such sharp banks occur rarely if at all between different levels of the Brickendon, or between Brickendon and Woodstock. This however might be accounted for by their removal by erosion, in the much longer intervals available.

Climatic fluctuations such as those of the Pleistocene, could result either in depositional or in cut terraces through changes in the volume and load of rivers entering the Basin and consequent changes in gradient of their courses across it. The gravelly nature of the Brickendon deposits, in contrast to the finer sediments of the Woodstock Surface, indicates markedly differing conditions of deposition. However, it is conceivable that the Brickendon surfaces might have arisen by planation in climatic conditions differing from those which permitted the original accumulation of the gravels. If the climatic hypothesis is accepted, similar climatic conditions during the shaping of each terrace must be envisaged, since the gradients of successive terraces appear to differ little if at all.

Joints and faults through the dolerite in the Cataract Gorge might be responsible for irregular variations in its resistance to corrasion, and this might be accentuated by variations in the load carried by the river. This mechanism would apply to intermittent rapid fall of base level after a period of stillstand and would result in terraces cut in earlier sediments.

The South Esk River crosses a horst in its course through the Cataract Gorge (Carey, 1946; Blake, 1959). If the faults have been active in comparatively recent times, they could be responsible for intermittent lifting of the river bed at the head of the Gorge, with consequent sedimentation upstream and later river planation of the new sediments as the dolerite bar was again cut down. Intermittent lowering of base level by faulting, resulting in cut terraces upstream, is also conceivable, though unlikely because it would involve a reversal of the direction of former movement at these faults. Carey (1946) considered that blockage of the valley at Evandale by basalt was the direct cause of the accumulation of the siliceous gravels of which the Brickendon Terraces between Evandale and Longford are built. On the other hand, if the formation of terraces is in fact due to renewed movements of the fault system, it is likely that this mechanism, and not the extrusion of basalt, would account also for the deposition of

the gravels. If so, the gravel deposits might be much younger than the basalt, which would be in line with the possibility of a pre-Woodstock age for the basalt discussed above. Banks (1958, p. 235) states " .... .... it would appear that faulting has occurred in Tasmania throughout the Cainozoic ". However, renewed faulting as the cause of terrace formation in the Launceston Basin must remain hypothetical, since no positive evidence to support it has been found. The gradients of the terraces do not appear to have been affected by warping of the basin floor, nor have youthful fault scarps been observed. Scarps relating to the formation of the comparatively young Brumby Terraces might be expected to be still recognisable.

In summary, several mechanisms may be postulated as responsible for the existence of the terraces of the South Esk system, but none has been proved. The Brickendon Terraces are built of post-basalt gravelly sediments near Evandale and Longford, but further upstream they may be largely cut in pre-basalt sediments though with a veneer of transported gravels. The Brumby Terraces and the Canola Floodplains may represent relatively young deposits partially filling old valleys within the Brickendon. Alternatively they may represent surfaces with a thin veneer of young transported material, but essentially cut by river planation in the post-basalt Brickendon deposits or in the pre-basalt sediments. Further field observations are needed, north of the Gorge to determine whether there is any continuation of these terraces there, and southward to determine the sediments of which each terrace is composed. Deep drilling at chosen sites may be required.

**2. Ages of the Surfaces, and Summary of Late Cainozoic History.**

Nye and Blake (1938) assigned a Lower Pliocene age to the pre-basalt sediments and Carey (1946) considered them to be Miocene and the basalts Pliocene. Gill and Banks (1956) on fossil evidence placed the sediments, or at least their lower members, as Eocene or Lower Oligocene; they considered the basalts near Launceston to be between the limits Lower Oligocene and Middle Pleistocene.

The present work introduces the Woodstock Surface as a possible time marker. The basalts at Deloraine-Westbury, and at Campbell Town are pre-Woodstock, but at Evandale the evidence is slender and the basalt may be either pre or post Woodstock. Owen (1954, p. 191) regarded the bauxite at Myalla, north-western Tasmania, as " younger than Miocene " and the other Tasmanian instances as " much older—probably Eocene ". While this may be true of some Tasmanian bauxites, those belonging to the Woodstock Surface, for example at Campbell Town, can hardly be older than Pliocene in view of the considerable degree of preservation of the surface. The age of the Woodstock Surface may well be the same as that of the bauxite at Myalla. Wells (1957) regarded as Quaternary the laterite capping basalt hills near Deloraine and Exton, here considered to be part of the Woodstock Surface.

The Brickendon Terraces are younger than the Evandale basalt, though how much younger is not clear. Though Carey (1946) considered the accumulation of siliceous gravels to follow immediately upon the basalt, there is an alternative possibility of a considerably younger age for the Brickendon Terraces if the hypothesis of renewed faulting discussed above is accepted. Like the Woodstock Surface, the Brickendon Terraces have lateritic soils. In several places, for example on the Midland Highway five miles north-west of Powranna, there are substantial outcrops of laterite. These outcrops are studded with the siliceous gravels, indicating that the laterite was formed in the Brickendon materials themselves, and not on earlier remnants of the Woodstock Surface buried by the terrace. Several writers have considered that climates of the Tertiary Period are necessary to account for lateritization. For instance, Owen (loc cit p. 191) states " The writer does not know of any locality in Australia where lateritization has proceeded to completion during the Quaternary Period ". On the other hand Edwards (1955, p. 26) discussing the same occurrences of laterite, suggests that those developed upon basalt may relate to an interglacial phase of the Pleistocene. Blake (1959) shows the Brickendon Terraces as Pleistocene, though his map does not disclose the evidence for this. Stephens et al (1942) regarded them as " Pleistocene moraine remnants ". They have not the form of moraines, though they may well be Pleistocene.

If the Brickendon Terraces are relegated to the Tertiary on account of the laterite upon them, the conclusion from this area must be that only the Brumby and Canola surfaces, and the windblown sands, are Quaternary. On this view, the climatic fluctuations of the Pleistocene, despite the glacial and periglacial conditions known to have existed in the catchments of rivers traversing the basin, have left very little imprint upon the basin itself. It seems far more reasonable to assign the Brickendon Terraces to the early Pleistocene, and their lateritization to one or more of the interglacial phases. The basalt at Evandale may then be as late as Pleistocene, as Gill and Banks (loc cit) suggest.

The Brumby Terraces and windblown sands are certainly Quaternary. It has been suggested (Nicolls, 1958*b*) that the windblown sands relate to the concluding phases of the last glaciation. The Canola Floodplains belong to the present day.

The late Cainozoic history of the Launceston Basin may then be reconstructed as follows:—

(1) Probably during the Pliocene, the Woodstock erosion surface was formed across early Tertiary sediments and across basalt and dolerite. It graded to sea level via the Tamar Valley. Heavy cappings of laterite developed on the basalt and dolerite, and lateritic soils with smaller occurrences of laterite, on the Tertiary sediments.

(2) The basalt at Evandale may have been already present at this time; if so, the Woodstock Surface presumably developed across it, but its soils have been almost completely stripped away since. Alternatively, the valley filled by the Evandale basalt had already been cut deeply into the Woodstock Surface.

(3) Either as an immediate consequence of the basalt eruption, or by later capture, the South Esk River was diverted by the basalt at Evandale, into the valley that later became the Cataract Gorge. By this time the present valley system had become well established through the Woodstock Surface, except for some later captures.

(4) Either together with the diversion of the river, or later as a result of renewed faulting, sediments largely consisting of siliceous gravels were deposited in the valley between Evandale and Longford, burying part of the basalt sheet. How far they extended upstream is not known.

(5) The Brickendon Terraces formed at successive levels in these gravelly sediments and further upstream either in the gravelly sediments or in the earlier Tertiary sediments. These terraces, and later ones of the South Esk system, graded to the dolerite bar in the Cataract Gorge. Lateritic soils developed upon the Brickendon Terraces and continued to develop on what remained of the Woodstock Surface.

(6) Excavation of the Tertiary sediments from the Tamar Valley had commenced before the eruption of the Evandale basalt and continued afterwards. The 300-330 foot terraces of the Tamar Valley developed at about the time of formation of the Brickendon Terraces, and similar lateritic soils formed upon them.

(7) The Brumby Terraces developed at a lower level than the lowest Brickendon Terraces. An appreciable time interval is indicated by the presence of lateritic soils on the lowest Brickendon Terraces and their absence from the Brumby.

(8) At stages subsequent to (5) and (6), but of unknown relationship to (7) the 100-140 foot Tamar terraces were formed and drowning of the Tamar Valley took place.

(9) Bevelling of parts of the Woodstock Surface and of the Brickendon Terraces at some time or times since (5) gave rise to the Cressy and Newham Associations of soils.

(10 Base level fell more than 10 feet below the level of the Brumby Terraces. In the resulting shallow valleys between remnants of the Brumby Terraces, braided streams supplied sands which were blown by prevailing winds onto the eastern valley sides. This event may date towards the close of periglacial conditions in the mountain catchments. The lunettes of Stephens et al (1942) may also belong here, or may be younger. On the Brumby remnants soil formation has continued with very little modification of the original groundsurface

(11) The present Canola Floodplains developed, partially burying dunes of sand.

(12) River captures have occurred from time to time since (5). The capture of the South Esk River at Evandale is an almost certain event for the future.

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Plate 1 (*a*).—Small basalt hill one mile south-east of Exton. Its capping of laterite (on skyline) 920 feet above sea level is considered to be a remnant of the Woodstock Surface.

Plate 1 (*b*).—The head of the Cataract Gorge near Hadspen, control point for terraces of the South Esk system. Dolerite hills on either side of the river, bevelled Brickendon terrace in the foreground. Water level here (415 feet above sea level) has been raised slightly by the Trevallyn dam.

Plate 2.—Brumby Terrace (left) standing 12 feet above Canola Floodplain (right), with typical sharp bank between. Abandoned channel characteristic of floodplain in foreground. Locality, one and a half miles south-west of Bishopsbourne.

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# GEOLOGY AND STRUCTURE OF THE MIDDLE DERWENT VALLEY

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(Communicated by Maxwell Banks, University of Tasmania)

(With 8 figures and 4 coloured maps)

## ABSTRACT

An area of 130 square miles of the Middle Derwent Valley lying between New Norfolk and Hamilton has been geologically mapped. The Permian sub-greywacke type sequence consists of 1300 feet of sandstone, siltstone, mudstone and limestone deposited on a stable shelf. Disconformably overlying the Permian are rocks belonging to the Triassic System which have been grouped tentatively into three formations. The Permian and Triassic are extensively and complexly injected by dolerite; mineralogical variations from the normal tholeiitic dolerite to granophyre have been traced. Evidence for liquid immiscibility is present towards the base of the sill. The Jurassic structure is interpreted as a cauldron subsidence. Faulting is accompanied by dolerite intrusion of transgressive to concordant sills, which are like cone-sheets near the root zone. Various Tertiary faults combine to form a stepped graben, the axis of which trends north-west, resulting in the formation of a chain of lakes and lowlands. In late Tertiary times, large outpourings of olivine basalt and associated tuffs, at least 350 feet thick, overran the lakes and partly filled the valley. Several flows of basalt have been mapped and five periods of volcanism have been recognised. The inter-basaltic periods are marked by either lake sediments or fossil forests. The graben faulting controlled the drainage pattern both during pre-basaltic times and subsequently.

## INTRODUCTION

The area mapped lies in the middle Derwent Valley comprising four ten-kiloyard grid squares, namely, Mt. Spode, Macquarie Plains, Glenora and Plenty and is covered by the aerial photographs Ellendale runs 1 to 10 and Styx runs 1, 2 and 4. Tertiary basalts were mapped on a scale of 1 inch equals 400 feet, using a base map, provided by courtesy of the Hydro-Electric Commission, Hobart. Details from this have been incorporated in the 1 mile = 1 inch map. Specimen and thin section numbers quoted refer to material lodged in the Geology Department, University of Tasmania.

## PHYSIOGRAPHY

The physiographic development of the area has been dominantly controlled by the structure and the complex intrusion of Jurassic (?) dolerite. The Derwent Valley is a graben. Permian and Triassic rocks with minor dolerite and Tertiary basalts and lake sediments form the valley, while dolerite hills like Mt. Spode, Mt. Belmont and Moogara Plateau border the valley on either side and rise to heights of 1,500 to 2,000 feet. Small hills of resistant Triassic sandstone and Tertiary basalt rise to 500-600 feet elevation in the valley. The area is drained by the Derwent and its tributaries i.e., Russell Falls, Styx and Plenty Rivers and smaller rivulets such as Allen Vale Rivulet, Belmont Rivulet and Dry Creek. The drainage is controlled for the most part by either the structure or resistant rocks. Though the elevation in the area does not exceed 2,000 feet, the gradient of the hills is quite steep and deep gullies have been cut in the resistant rocks. The physiography could be said to be in a late youthful stage.

## PERMIAN SYSTEM

### General

Rocks belonging to this system have received great attention in the Hobart district and several geologists have studied them. Voisey (1938), Lewis (1946), Banks (1952, 1955) and Banks and Hale (1957) are responsible for the present knowledge of the Permian rocks in Tasmania. Permian rocks from the Bundella Mudstone upwards are exposed in the area on the upthrown side of the Glen Fern Fault and west of Glenora up to Westerway.

### Bundella Mudstone

The top 35 to 40 feet of this formation are exposed on the upthrown side of the Glen Fern Fault at grid 489.000, 733.050. The rock is an olive grey, non-fissile siltstone, with angular fragments of quartz, feldspar, muscovite and rock fragments with glacial erratics of quartzite and phyllite ranging in size from a fraction of an inch to a couple of inches.

* Published by the permission of the Director, Geological Survey of India.

### Faulkner Group

This group is exposed overlying the Bundella Mudstone. The first member is a quartz-rich, fissile, thinly bedded sandstone, noticeably micaceous and in parts cross-bedded. Overlying this is a six feet thick, well-sorted, olive grey carbonaceous siltstone which is unfossiliferous except for vague plant fragments. The section above this is covered for a height of 60 to 70 feet. The next member seen is a pale yellow to orange coloured feldspathic sandstone with angular to sub-angular fragments of quartz and feldspar with patches of bryozoa. This formation is correlated with the Rayner Sandstone (Banks and Hale, 1957).

The correlation of these formations from the upper Bundella through the Faulkner Group to the Rayner Sandstone is open to question. There are neither good sections nor is there diagnistic fossil evidence to prove or disprove the correlation. This correlation is suggested because these formations underlie the Cascades Group with diagnostic fossil evidence and within the area there appears to be no structural discontinuity.

### Cascades Group

A good section of this group is exposed on the spur going south-south-east from the Glen Fern-Moogara road crossing from 450 feet to 770 feet and overlies the Faulkner Group. The Dry Creek Fault throws down the section on the west side by at least 150 feet. The Cascades Group in this locality is approximately 320 feet thick and consists of Nassau Siltstone, Berriedale Limestone and Grange Mudstone.

The Nassau Siltstone is 10 to 15 feet thick and contains angular grains of quartz, and little feldspar. Numerous fossils are present, especially species of *Strophalosia* and *Fenestella*. The other fossils are pectinoids, spiriferids and fragments of pelecypods. Towards the top the formation becomes more calcareous.

The calcareous siltstone and limestone about 150 feet thick form the Berriedale Formation. Individual beds are a few feet thick separted by thin fissile siltstones. The limestones range from calcirudite to calcilutite. They are generally impure and consist of clastic grains of quartz and erratics of quartzite and other metamorphic rocks. Important fossils are species of *Fenestella, Stenopora,* Spiriferids, *Aviculopecten* and corals. Towards the top the limestone passes into Grange Mudstone.

Grange Mudstone is exposed both on the east and west side of Dry Creek and attains a thickness of 150 to 160 feet. Here the formation consists of non-fissile to fissile siltstone. The rocks are mostly yellow to brown and rich in fossils. Erratics are common. Another small outcrop of Grange Mudstone is exposed a mile and a half south of Westerway on the first bench of the dolerite hill.

### "Woodbridge Glacial Formation"

This formation attains a thickness of 280 feet and is composed of rhythmic alternation of sandstone and siltstone. The rocks are grey when freshly broken and weather to yellow and yellowish brown. Erratics are more profuse than in the underlying or overlying formations. Towards the base and 50 feet from the top fossiliferous siltstones occur. The top horizon forms a marker bed and is exposed near grid 489.900, 731.000.

### Risdon Sandstone

Overlying the "Woodbridge Glacial Formation" is an 8 to 10 feet thick bed of feldspathic sandstone with coarse, sub-rounded quartz and feldspar; it is unfossiliferous.

### Ferntree Mudstone

The Ferntree Mudstone lies above the Risdon Sandstone and below the Cygnet Coal Measure or where the latter is absent below the Triassic Ross and Knocklofty Formations. Ferntree Mudstone is exposed on either side of Dry Creek and attains a thickness of 400 feet and is faulted against the dolerite. In the Karanja and Westerway area it attains a thickness of 600 feet. Good exposures are seen in the railway and P.W.D. quarry near Westerway. West of Karanja a certain amount of baking is noticed due to the proximity of the dolerite roof. North of Russell Falls River this formation is disconformably overlain by the Triassic sandstone. Besides the Risdon Sandstone three more sandstone horizons are noticed in the Ferntree Formation, along the numerous timber tracks north of Westerway and along the track west of grid 488.500, 730.900. Such quartzose members in the Ferntree Formation are described by McKellar (1957, pp. 8-9) from the Great Lake area.

## TRIASSIC SYSTEM

### General

Disconformably overlying the Permian System is a group of Triassic to Lower Jurassic age. This disconformable relation was earlier recognised by several workers (Nye, 1921, 1924; Hills and Carey, 1949; and Banks, 1952). The erosional break is seen at grid 475.000, 746.400, and 471.100, 745,000 and west of Hollowtree Road. At the first two localities an angular unconformity is suggested by the discordant attitudes of the Permian and Triassic beds.

The subdivision of Triassic rocks into different formations is difficult owing to rapid facies variations and lensing out of beds. Jennings (1955, p. 175) expressed a similar opinion with regard to the Wayatinah area. General lithology and fossil evidence, at the present state of knowledge, do not allow definite correlation. However, two distinct formations can be recognised, the Knocklofty Sandstone and Shale and the "Feldspathic" Sandstone. Towards the base of the system the members are essentially coarse to medium quartz sandstones, massive in nature with very minor amounts of shale beds, the sandstones exhibiting pronounced cross-bedding and slump structures. These, where exposed, form a distinct group of beds forming cliffs with salt efflorescence and can be recognised as a formation. McKellar (1957, p. 4) has described 650 feet of massive quartz sandstone from the Great Lake area which he has grouped as Ross Sandstone. Further work on the Triassic stratigraphy is needed to decide the stratigraphic status of these, either as a separate formation, or as a basal member of the Knocklofty Sandstone and

Shale. Since these form a recognizable unit they deserve to be considered separately and in this area such rocks have been mapped as Ross Sandstone.

### Ross Sandstone

Sandstones recognized as Ross are exposed on the fault-line scarp of the Magra Fault, on the Norton-Clarendon Horst and west of Allen Vale Rivulet forming a strike ridge in the latter area. Lithologically they consist of conglomerates towards the base and sandstones towards the top. The conglomerates are mainly quartz conglomerates containing pebbles of reef quartz, quartzite and intraformational mud pellets, set in a quartzose matrix. The sandstones are medium to coarse-grained with white, sparkling quartz and authigenic silica as cement. Minor amounts of muscovite, graphite and iron oxide are present.

These sandstones are thickly-bedded and show sigmoidal cross-bedding and slump structures in the Norton-Clarendon Horst and on the Magra fault-line scarp. In the latter locality alternation of coarse and medium-grained sandstones occurs; each major alternation is of the order of 60-80 feet with minor rhythms included in them. The cross-bedding and slump structures indicate a current direction from north-west with a south-east sloping floor. These sandstones weather into white sandy soil and support a dense bracken fern vegetation.

### Knocklofty Sandstone and Shale

This formation overlies the Ross Sandstone and is exposed in the Plenty area on the downthrown side of the Glen Fern Fault and east of Gretna and Mt. Spode.

The sandstones are white to grey, and consist of feldspar (10%), with minor amounts of muscovite and graphite along bedding planes. The cementing material is usually argiliaceous with varying amounts of iron oxide. The sandstones are thinly-bedded to flaggy and friable. Sedimentary structures such as cross-bedding and ripple marks are common. Intraformational mud pellets are not uncommon and form beds up to three to four inches thick.

The argillaceous sediments range from siltstones to shales and interdigitate with the sandstones . A dirty green colour is most common, while purple and white colours are also frequent. These lutites break into rectangular blocks. On the Moogara Road at grid 486.000, 733,500 is a bed of mudstone, dark brown to purple in colour, with mottling of purple blotches. When freshly broken it is dirty green in colour. In the road cutting at least 10 feet is exposed and the thickness is probably even more. Jennings (1955, p. 178) records a 100 feet thick bed of dense mudstone at Wayatinah.

A conglomerate bed, 30 to 35 feet thick, occurs in this formation in the north-west trending spur north of Peckham Vale and the north-south ridge west of Allen Vale Rivulet, at an elevation of 1,100 feet. This is underlain by Ross Sandstone nearly 400 feet thick.

Plant fossils are common in the shaly beds. *Dicroidium odontopteroides* is found east of Rose Garland; worm casts are also found in the shale beds at grid 486.900, 747.800.

### "Feldspathic" Sandstone

This formation overlies the Knocklofty Formation and is overlain unconformably by the Tertiary lacustrine sediments or basalts. Good sections are exposed in the Plenty area, around Salmon Ponds along the Lyell Highway from Gretna to Bluff Road.

Here the formation consists of medium to fine grained feldspathic sandstones with interbedded shale, carbonaceous shale and inferior coal. The sandstones consist of angular to sub-rounded grains of quartz, feldspar, mica and rock fragments, set in an argillaceous to chloritic matrix. A calcareous matrix is not uncommon. The feldspar is usually fresh but when exposed on the weathered surface it is kaolinised and gives the rock a speckled appearance. Shaly members are fine grained and range from white or grey to black and carbonaceous. Those at Plenty east of the basalt quarry on the Lyell Highway contain minute crystals of gypsum. Inferior coal occurs at Plenty and near Marshall's house at Macquarie Plains. Cross-bedding is common in the sandstones and indicates a current direction from west-north-west and north-north-west.

A thin section of the feldspathic sandstone (8707) consists of 50% sub-rounded to rounded grains of quartz, 20% anhedral grains of feldspar (orthoclase and plagioclase) and 25% of angular rock fragments set in an argillaceous matrix. The angular rock fragments include quartzite, schist and some basic igneous rocks.

### Environment and Sedimentation

The Triassic rocks are members of the ortho-quartzite suite of Pettijohn (1949) with the possible addition of volcanic material, all deposited under lacustrine or swampy conditions on a shallow, slowly sinking floor. During the "Feldspathic" Sandstone time possible addition of volcanic material is suggested by the fresh plagioclase. The presence of angular rock fragments suggests an elevation of source land and indicates that earth movements or volcanism became active during this period.

## JURASSIC (?) DOLERITE

Extensive intrusions of dolerite which took place after the deposition of Triassic rocks form the next common rock in the region and are exposed over a wide area. The contacts with the pre-dolerite sediments are either sill-like or discordant. The most irregular intrusions are in the Permian and the Knocklofty Formation in the Glenora and Mt. Spode map sheets. Generally the base of the sill is uniform while the roof zone is quite irregular and rafts of sediments are a common feature on the sheets quoted.

Contact metamorphism is a very minor feature. The sediments are rarely altered for more than a few feet away from the contact. Usually no effects

are visible i the dolerite 50 to 100 feet away from the contact. At the intrusive contact the dolerite is chilled with phenocrysts of orthopyroxene. Away from the contact zone the dolerite is medium to coarse-grained, grainsize increasing towards the top of the sill. It is generally massive with crude columnar jointing and develops a system of cooling fractures near the contact.

Dolerites weather in a spheroidal form and the extent of weathering is quite irregular. Although near faults the weathering may be intense and may extend to a greater depth, generally the depth of weathering is only a few feet. Dolerite gives rise to extensive talus and scree material on steep hill slopes and thickness of this may be very variable.

The age of the dolerite intrusion cannot be fixed with any degree of certainty. Lewis and Voisey (1938, p. 38) and later authors have suggested a Jurassic age for the Tasmanian dolerites. The present investigation has produced no new evidence to vary this view.

### Petrology

The petrology of the Tasmanian dolerites has been described by Edwards (1942). It is proposed in this section not to discuss the petrology in detail but to place on record a few outcrops of petrological significance.

A specimen collected from the contact of dolerite and basalt at grid 483.000, 751.900 is interesting. The rock in hand specimen (8683) is fine-grained, light buff-coloured with a granophyric texture. Under the microscope it has a complex texture, which appears somewhat igneous, and consists of quartz (55%), orthoclase (35%), with ferromagnesian mineral (10%), mostly mica and chlorite. No pyroxenes were seen. The quartz grains are anhedral and have irregular margins riddled with inclusions, the central portion of each grain being free from inclusions. The feldspar is mainly orthoclase. While this also has irregular margins, projecting outwards are lath-shaped protrusions giving an amoeboid appearance. Between these grains of quartz and orthoclase are randomly oriented lath-shaped bodies, probably plagioclase, giving a texture like that of the dolerite.

The texture and composititon of the rock may have arisen in one of two ways. Firstly, the rock could be a dolerite, silicified by the contact metamorphism of the overlying basalts, thus retaining remnants of igneous texture; secondly the rock couid be an extreme differentiate of the dolerite magma giving rise to a granophyre. In this case the former view is suggested, since the outcrop is in contact with Tertiary basalt.

A specimen collected south-east of Rose Garland at grid 484.600, 743.300 is a fine-grained and dense rock with a dark greenish-grey colour. The rock shows amygdules filled with calcite and quartz and shows nodules of a dark material. In hand specimen it could be mistaken for amygdaloidal basalt. Under the microscope the rock is fine-grained dolerite with plagioclase (50%), pyroxene (30%) and mesostasis. The dark amydgaloidal nodules under the microscope appear to be of fine mesostasis surrounded by the normal fine-grained dolerite. The edge, often sharp, is lined with tiny laths of piagioclase (slide 8691).

The occurrence of distinct globules of mesostasis within the fine-grained dolerite may be explained either as a result of liquid immiscibility or the squeezing of mesostasis into the vesicles. Direct evidence of silicate immiscibility in nature is lacking. Roedder (1951, p. 282) found an extensive region of immiscibility in the system of $FeO$-$K_2O$-$Al_2O_3$-$SiO_2$. A series of quenching experiments conducted by Cassidy and Segnit (1955, p. 305) on an artificial mixture of soda, lime, magnesia, alumina, and silica, approximating in composition to iron-free tektite, resulted in a small sphere of one type of class embedded in much larger quantities of a second class. From these experiments and other experiments on actual tektite, they concluded "that the so called 'lechatelierite' inclusion in tektites most probably represents a state of liquid immiscibility in a silicate melt". This occurrence of globules of fine mesostasis in a fine-grained dolerite may be a case of natural liquid immiscibility in a silicate melt.

An advanced stage of the differentiation of dolerite magma occurs in the Bloomfield area at grid 490.000, 754.500. Specimens 8684, 8685, 8680 and 8688 were collected from different zones commencing from what was recognised in the field as dolerite to granophyre. Specimen 8689 was collected from the northern slope of the adjacent hill. Mineralogical variations are represented in the two diagrams Figs. 1 and 1a. Specimens 7544, 7550 and 7558 are from the Mt. Wellington sill and specimen 3250 is from the Red Hill granophyre.

On the orthodox view of differentiation by crystal settling, the decrease in the percentage of pyroxene up to sp. 8685 is normal, but the increase seen in spp. 8680 and 8688 is anomalous. The increase of quartz and orthoclase is to be expected. The reason for the iron oxide increasing up to sp. 8685 could be that the pyroxene separating out is pigeonite low in iron. The sudden decrease in the percentage of iron could mean that the excess iron goes to pyroxene and separates out as iron-rich augite, ferro-augite. In the same specimen the mesostasis is also greater and the lighter residue rich in $K_2O$, $Na_2O$, $SiO_2$ and $H_2O$ separates out as quartz and orthoclase in the next higher fractions. Here it is noticed that there are two unconnected trends, one separating as granophyre and the other separating as pegmatite. The granophyre separation could occur in the normal course of differentiation with enrichment of lighter residue as stated earlier. The pegmatite could possibly separate with enrichment of water at an earlier stage with the formation of pigeonite instead of ferro-augite. This divergence in trend from the mesostasis-rich zone may be due either to enrichment of water at different times or to variations in the thickness of the column of magma differentiating, or possibly to both. Thus the differentiated dolerite at Bloomfield forms the link between the Mt. Wellington dolerite and the Red Hill granophyre (see slides 3250 and 8680).

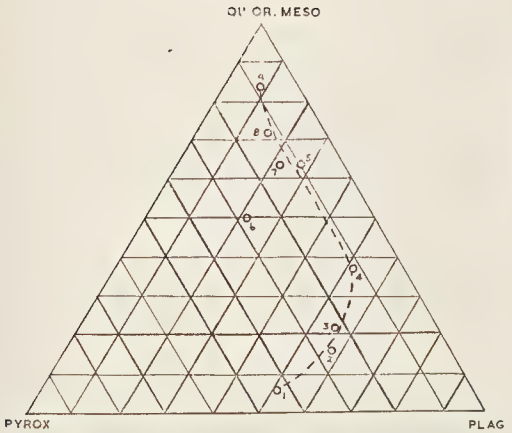



FIG. 1 VARIATION DIAGRAM OF BLOOMFIELD DOLERITE.

| | | | |
|---|---|---|---|
| 1 | MT. WELLINGTON SILL | BTM | 7544. |
| 2. | ,, | MIDDLE | 7550. |
| 3 | ,, | TOP | 7558. |
| 4-8. | BLOOMFIELD DOLERITE | 8684, 8685, 8689. 8680 8688 | |
| 9. | RED HILL GRANOPHYRE | | 3250 |

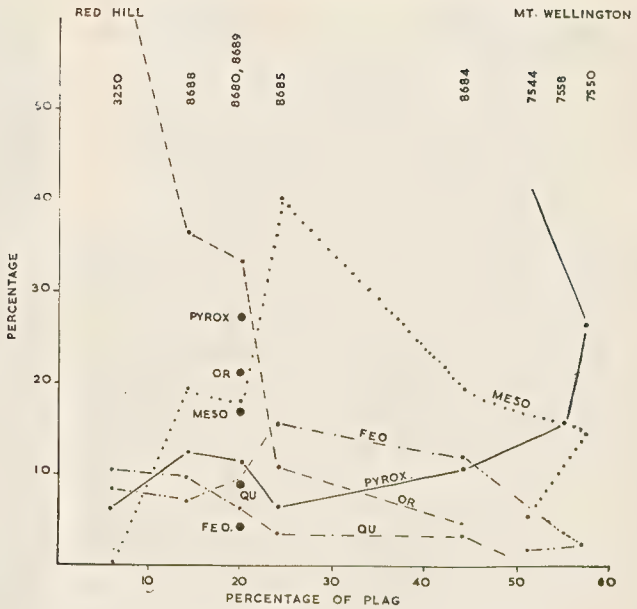



FIG 1A VARIATION DIAGRAM OF BLOOMFIELD DOLERITE

## TERTIARY SYSTEM

### Tertiary Lake Sediments

Earlier references to the Tertiary lake sediments in this area are few in number. Johnston (1888) described the fossiliferous lignites and clays from the junction of the Styx and Derwent Rivers. Banks (1955, p. 9) made a brief reference to these sediments.

Th Glenora and Bushy Park area formed a lake bottom during the period prior to Tertiary volcanism. Banks (1955, p. 8) called this the 'Glenora Lake'. This lake extended from Meadowbank Road to Plenty in a south-easterly direction and from Clarendon homestead to the present Styx River in a north-south direction. The basal conglomerate bed exposed in the Norton and Clarendon property, on the Meadowbank Road, and on the Dobson Highway west of Glenora marks the northern and western limits to this lake. The basal conglomerate bed at the Norton property and on the Meadowbank Road is 30 to 40 feet thick and contains boulders of dolerite, pebbles of Precambrian (?) quartz schist and Owen Conglomerate. The pebbles of the conglomerate bed on the Dobson Highway show a high degree of rounding and polishing. The fossil wood lying on the high dip slope at Meadowbank and the polishing of pebbles probably indicate a steep precipitous western edge to the lake. Subbasaltic conglomerate beds are seen near Macquarie Plains station and in the Plenty basalt quarry. Interbedded with the conglomerates are sandstones. When the lakes were dry these sandstones formed a soil cover supporting forests. Overlying the conglomerate beds are 150 to 200 feet of siltstones, claystones and feldspathic sandstone. Good sections of these are seen in the Glenora area. The clay beds contain leaf impressions. During volcanic quiescence sediments accumulated on the uneven surface of the basalt country and such interbasaltic sediments are seen in the Kenmore basalt hill.

### Tertiary Basalts

The Tertiary basalts cover an area of 19 square miles. The greatest development is seen in the Glenora, Macquarie Plains and Norton areas extending from the Hamilton map sheet to Plenty. Two isolated exposures occur in the Plenty map sheet. In the Glenora and Bushy Park area the basalts attain a thickness of 350 feet and in the Plenty area a thicknes of 120 feet. Looking at the areal distribution it appears that the basalts are confined to the valley areas and that the exposures at Plenty were once continuous with the main basalt sections at Bushy Park.

#### *Age of the Basalts*

The age of the basalts in Tasmania is not everywhere well established. Different ages have been assigned to basalts in different parts of Tasmania, commencing from Oligocene for the basalts of the Midlands (Nye and Blake, p. 26), to early Pleistocene for the basalts of the Central Plateau (Lewis, 1935, p. 176). In the Wynyard District they overlie and underlie the Fossil Bluff Sandstone of Upper Oligocene age (Gill and Banks, 1956, p. 11) and in the vicinity of Hobart and Launceston they overlie leaf-bearing sediments of the Laun-

ceston and Derwent basins (Edwards 1949, p. 99). The youngest dated sediments under the basalt in the Launceston area and in the Ouse area of the Derwent basin are Lower Oligocene or older (Gill and Banks, 1956). Edwards (1949, p. 115) showed that the Tasmanian basalts exhibit petrological affinities with both pre- and post-Miocene volcanic rocks of Victoria. No evidence is yet available from this area as to the age of the basalt.

In the Glenora and Bushy Park areas seven flows have been recognized and their correlation within this area has been established from several measured sections and a summarised sequence of the Tertiary volcanic history is presented in Fig. 2. The tuff horizons have been interpreted as explosive phases and the sub-basaltic conglomerate and sediments have been taken to represent periods of quiescence. There have been five periods of volcanic activity in each case an explosive phase followed soon after by a flow except in the case of flow 2. The periods of quiescence were possibly of a great length, sufficient to cool the lava field and to support vegetation and forest of at least a thousand years standing. Flow 7 may not have been the final flow as the Derwent River has eroded the upper surface of the Kenmore hill.

GENERALIZED SEQUENCE OF TERTIARY BASALTS AND LAKE SEDIMENTS IN GLENORA AND MACQUARIE PLAINS AREAS

Indicating fossil wood horizon & volcanic phases

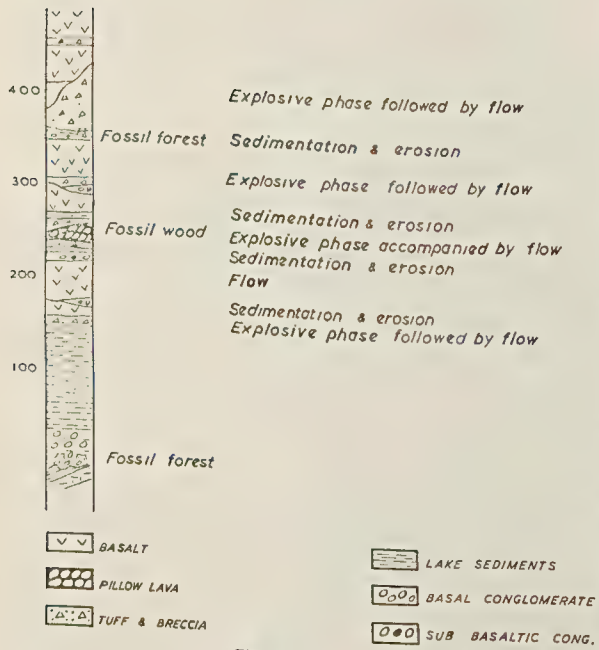



FIG. 2.

The pattern of the basalt outcrops downstream from Ouse suggests that the basalt flowed down the valley. In addition there appears to have been a chain of centres along the graben, all tapping portions of the same magma chamber and thus having a very close resemblance in chemical and mineralogical composition. The thick tuff bed at Kenmore hill and the dip of the flows east of Allen Vale Rivulet suggest a possible centre between Allen Vale Rivulet and Clarendon trig station.

The basalts of the Glenora-Bushy Park areas are of two types, according to Edwards' classification (1949), namely Ouse Type, and Bridgewater Type with some intermediate varieties. The classification is purely textural and relates therefore to the cooling history. The type depends on the thickness of flow and condition of cooling.

## QUATERNARY SYSTEM

The post-Tertiary has been a period of erosion and deposition along river courses. Rocks of this period include superficial deposits of rock slides, screes, talus, and river gravels. River gravels and alluvium are best developed along the Derwent River. Three terraces have developed at altitudes of 500 feet, 350 to 400 feet, and at 200 feet, the present terrace being at 75 to 100 feet. Of these the 200 feet terrace is most extensive and extends from the mouth of the Styx River to New Norfolk. The first two river terraces are post-basaltic and pre-Quaternary in age.

## STRUCTURE

The structure of the area is dominated by the effects of two periods of epeirogeny, one during the Jurassic and the other during the Tertiary, as established by Carey (1954, pp. 189-191). During the Jurassic, widespread block-faulting occurred, as well as some cauldron subsidence. This was followed by intrusion of tholeiitic magma, in the form of concordant and disconcordant intrusions. The resultant uplifted topography was subjected to a long period of erosion and peneplanation which lasted many millions of years and produced a mature peneplain (Carey, 1947, pp. 31-46). Owing to this long peneplanation, isostatic inequilibrium was set up and culminated in strong epeirogeny during the Tertiary. This epeirogeny has resulted in graben faulting and was followed by volcanic activity with outpouring of olivine basalt. Due to these two superimposed epeirogenies the structure caused by the latter is more pronounced than that of the former, and has even obliterated the earlier one to some extent.

### Jurassic Structure

*Bloomfield Fault*

The dominant Jurassic structure is the Bloomfield cauldron subsidence in the Mt. Spode map sheet. The Bloomfield Fault forms a partial ring fault, a 90° arc of a circle, bringing the Triassic Knocklifty Formation against the Ferntree Formation with an estimated throw of 1,000 feet. In the middle of the arc, is a dyke-like body which Carey suggests (pers. comm.) acted like a feeder to the main intrusion. The Bloomfield ring fault has

been cut off on the south-eastern side by the Askrigg Fault (= Black Hills Fault of Macquarie Plains map sheet; renamed to prevent confusion with the Black Hills Fault of Woolley (1959) which is not continuous with it) of Tertiary age. The physiographic expression of this Bloomfield structure is that the Bloomfield area forms a flat-lying area with a Triassic raft at an elevation of 1,100 feet. Immediately inside the peripheral fault, dolerite forms a circular ring, with an average relief of 300 to 500 feet above the surrounding country. Through this ridge, deep gullies have been cut, along tensional joints leaving steep sided hills.

To relieve the stress, radial faults have developed half a mile north-north-east of Peckham Vale house, west of the Allen Vale Fault and at the eastern end of the map sheet just outside the area. The Peckham Vale Fault runs in a north-westerly direction with an estimated downthrow of 500 feet to the north-east. The Triassic formations have discordant attitudes on either side of the fault. Further north-east along this fault dolerite has been intruded.

The fault at grid 488.500, 748.100 runs in a north-westerly direction and a strong linear is visible on the aerial photos. The displacement deduced from the relation of Ross and Knocklofty Formations is of the order of 300 to 400 feet. The age of this fault is open to doubt. The pattern of dolerite outcrops suggests a post-dolerite age but at grid 488.050, 749.050 baked Triassic sandstones and shales of the "Feldspathic" Formation indicate a pre-dolerite age. In the present work the age of this fault is taken as Jurassic. The third radial fault falls just outside the Mt. Spode map sheet and hence is not considered here.

Running across the Black Hills Road is a Jurassic fault trending 350° with a very steep dip towards the west. This fault stops at the Triassic-dolerite contact in the south. Along this pre-dolerite fault dolerite has intruded as a dyke 15 feet wide and exhibits evidence of post-dolerite movement with brecciation, shattering and deposition of secondary calcite along the fracture planes.

*Jurassic faults in the Glenora area.*

West-north-west of Glenora on the north side of the Russell Falls River is an east trending Jurassic fault with throw to the south. This fault acted like a feeder to the dolerite intrusion which has spread as a transgressive sill on both sides of it. From the base and roof relation of the sill, the throw on this fault may be anything from 1,000 to 1,500 feet.

The Karanja-Westerway strip forms an upthrown block bordered by two sub-parallel Jurassic faults trending roughly 300°. In the Westerway area there are four Jurassic faults trending 270° and 300° producing a wedge-shaped, down-faulted block of Knocklofty Formation. Along Dry Creek in the Plenty area is another Jurassic structure trending roughly north.

To visualise the Jurassic structure in the presence of Tertiary epeirogeny is difficult. However, an attempt is made here and the following pattern is suggested:—

1. The Bloomfield area formed a centre of dolerite intrusion. The Bloomfield Fault formed a partial ring fault accompanied by cauldron subsidence.
2. The stress on this ring fault was relieved by radial and peripheral faults and radial tension joints.
3. The two sub-parallel faults in the Glenora-Westerway area possibly formed faults tangential to this major structure.
4. Dolerite has intruded these structural weaknesses as transgressive to concordant sills and the intrusion of the dolerite is wholly or partially controlled by these faults.

From the Jurassic structural pattern described the Gretna Fault may be a Jurassic structure, but the base and roof relation of the dolerite outcrop, around the Hollowtree Road suggests a Tertiary age. To explain both the features it is suggested that Tertiary movements occurred along a Jurassic linear.

**Nature of Dolerite Intrusion**

To understand the nature and form of the dolerite intrusion a structural contour map has been constructed from the elevation of the dolerite contact with pre-dolerite sediments (Fig. 3). The structural map is a reasonable first approximation. The structure and form of the dolerite deduced from it fit into the known field evidence and give reasonable sections.

From the structural map it is seen that the dolerite intrusion in the Bloomfield area originated as an east-west dyke and spread as a transgressive sill accompanied by the Bloomfield cauldron subsidence. The structure is interpreted as a small cone sheet, dyke-like in its root zone (Fig. 4). This is corroborated by the field evidence of a steep shelving contact in the north, a conformable contact in the south, and the final granophyric differentiate of the dolerite at the suspected dyke position.

The block south-west of the Allen Vale Fault is the roof zone of a down-faulted portion of the sill rising towards the north-east. The successive blocks southwards form down-faulted blocks of the same intrusion let down and tilted by the Tertiary faults. The Belmont dolerite block forms a sill rising towards the north-east and transgressing stratigraphically from the Knocklofty Formation to the "Feldspathic" Formation.

The Mt. Spode portion of the sill again stratigraphically transgresses from the Knocklofty Formation to the "Feldspathic" Formation to the east. On the left bank of the Derwent River are a few dolerite exposures which form the erosional outlier of the Bloomfield sill.

The dolerite exposures on the right bank of the Derwent River in the Glenora and Moogara area may be upthrown blocks of the same intrusion or may have originated from a different centre. The dolerite block east of Upper Plenty rises topographically towards the east and stratigraphically from the Cascades Group to the Knocklofty Formation.

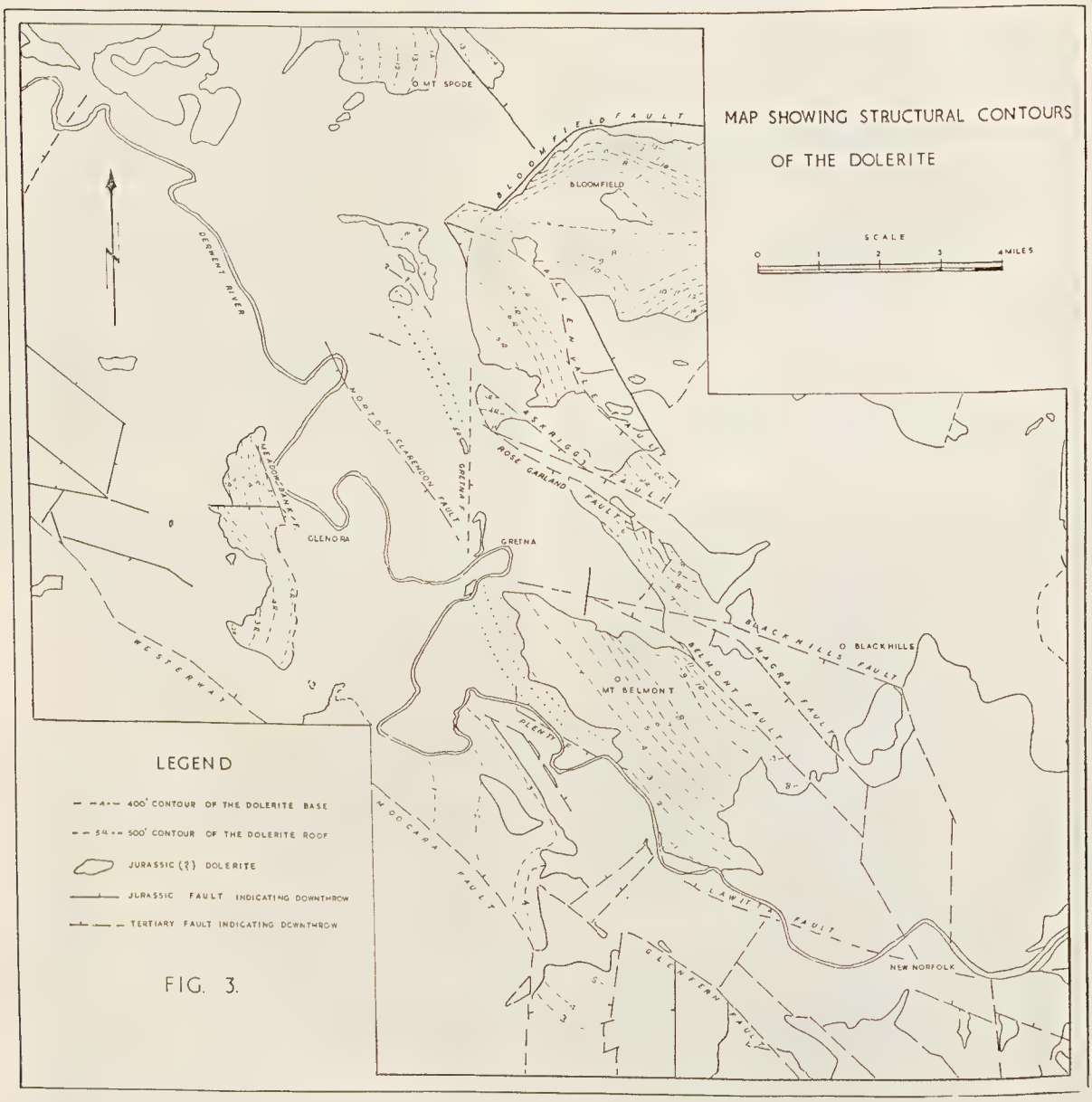



FIG. 3.

FIG.4 DIAGRAMMATIC SECTION ACROSS BLOOMFIELD INTRUSION

Sufficient data are not available to construct the structural contours for the Moogara-Westerway dolerite block. The dolerite block west of Glenora has intruded along a Jurassic fault, the southern portion being a roof zone rising eastwards, while the northern portion rises westwards.

### Tertiary Structure

The Tertiary epeirogeny resulted in block faulting of graben type with major faults generally trending at 300° and minor and secondary faults trending at 340° and north-east. The important major faults are Glen Fern, Moogara-Westerway and Lawitta Faults on the western and south-western side of the Derwent River and the Plenty, Belmont, Rose Garland (= Magra Fault of Macquarie Plains Sheet), Askrigg and Allen Vale Faults on the east and north-eastern side of the river with throw towards the north-east and south-west respectively. These major faults lie on either side of a line extending from New Norfolk to Glenora and from Bluff Road to Hamilton. Faults on the southern side of this line have a downthrow to the north-east, while those to the north of the line have a downthrow to the south-west, producing a graben. The Glen Fern and Moogara-Westerway

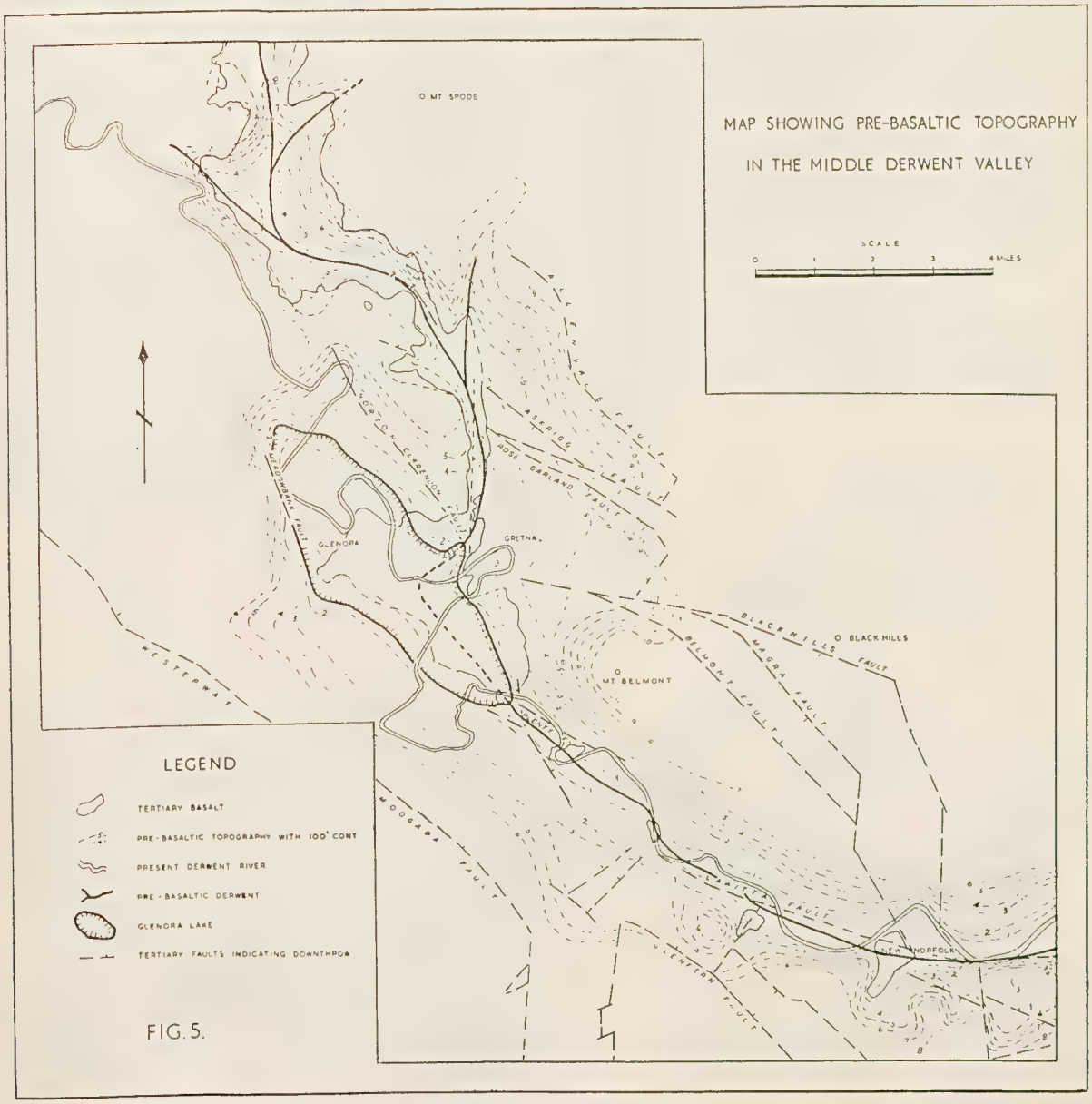



FIG. 5.

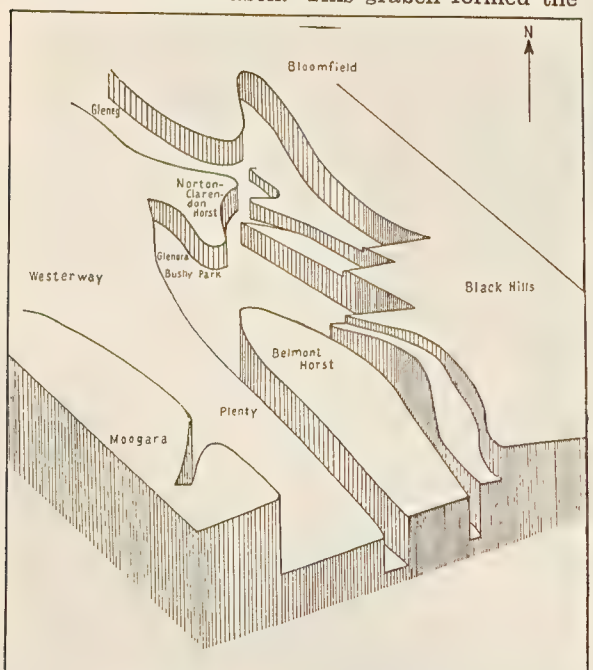
Faults extending over 15 miles with a throw of 1,800 feet to the north-east form the south-western limit of the Derwent Graben. The Lawitta Fault, with its probable continuation with the Meadowbank Fault, with a throw of 500 feet, again to the north-east, forms the inner limit of the graben. These two sub-parallel faults have a cumulative throw of 2,300 feet. The Plenty and Belmont Faults add another 500 feet or so.

On the northern side of this axis are again three sub-parallel step faults. The Rose Garland, Askrigg and Allen Vale Faults have a total throw of 2,800 feet towards the south and south-west and form the northern side of the Derwent Graben. The Gretna and Norton-Clarendon Faults form a horst in this graben. Similarly the plenty and Belmont Faults form another horst extending in a north-westerly direction roughly parallel to the graben axis. These two horsts lie *en echelon* on opposite sides of the graben axis.

All major faults are normal gravity faults. The major trend being 300°, the stress direction is at right angles to it, i.e., 30°, and is tensional. A secondary stress field was probably present which accounts for the other faults in the 340° and north-east direction.

## EVOLUTION OF THE MIDDLE DERWENT VALLEY

The history of the middle Derwent Valley commences after the Tertiary epeirogeny, which initiated the Derwent Graben. This graben formed the main drainage channel during the post-epeirogeny-pre-basaltic times and post-basaltic times. A map of the pre-basaltic valley as it existed after the Tertiary faulting is shown as Fig. 5. The diagrammatic sketch (Fig. 6) is a perspective view. In the discussion that follows, it is assumed that there has not been any differential movement since the extrusion of the basalts and the discussion should be read with the proviso that post-basaltic movement, if subsequently proved, could affect the interpretation.




DIAGRAMMATIC RECONSTRUCTION OF MIDDLE DERWENT VALLEY AFTER THE TERTIARY EPEIROGENY

FIG. 6.

From the contour map (Fig. 5) it is seen that the graben floor was very uneven with steep fault scarp faces and elevated horsts. The Norton-Clarendon Horst was roughly 600 feet high and the Belmont Horst was 1,500 feet high plus the amount which has been eroded since then. The sides of the graben were at least 2,000 feet high. North-west of Norton trig. Station it is seen that the basalts cut the 300 feet contour and do not cut the lower contours on the south side, indicating that this side formed a saddle between the "Glenora Low" and the "Gleneg Low". Attention is drawn to the fact revealed by the contours shown in the map that the basalt on the "Gleneg Low" goes down to below 300 feet above sea-level, whereas the 300 foot contour on the "Glenora Low" is shown closing three or four miles downstream. The floor of the basalt in the intervening valley seems to have been 100 to 200 feet higher than in the "Gleneg Low". Therefore it is inferred that the graben was very uneven with lakes and low-lying areas. The pre-basaltic Derwent flowed through these low-lying areas and lakes connecting them through a series of cascades and rapids. The ancestral Derwent and two other streams, one from the west and one from the north-east flowed into the "Gleneg Low". The Russell Falls and Styx Rivers flowed into the Glenora Lake. These two lows were connected by the pre-basaltic Derwent flowing roughly parallel to the Lyell High-

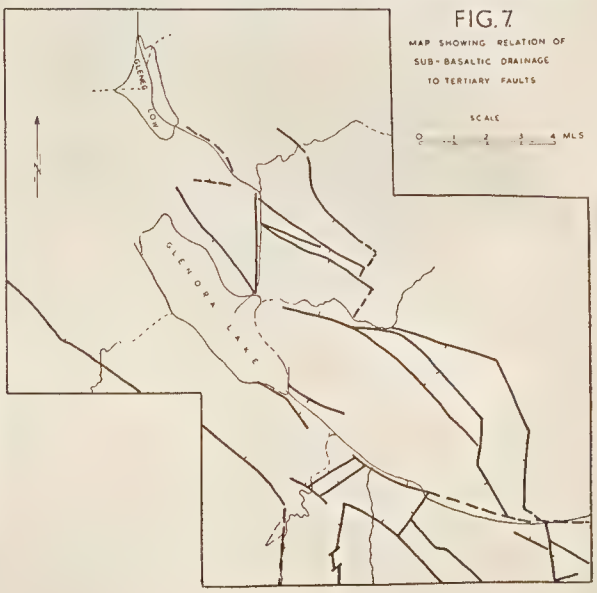



FIG. 7

MAP SHOWING RELATION OF SUB-BASALTIC DRAINAGE TO TERTIARY FAULTS

way under the basalt-filled area. The Allen Vale and Belmont Rivulets joined this from the north and east. The drainage pattern immediately after an epeirogeny is normally understood to be controlled by the structure. In this respect the ancestral Derwent was no exception and its course was controlled by the Tertiary faults (see Fig. 7).

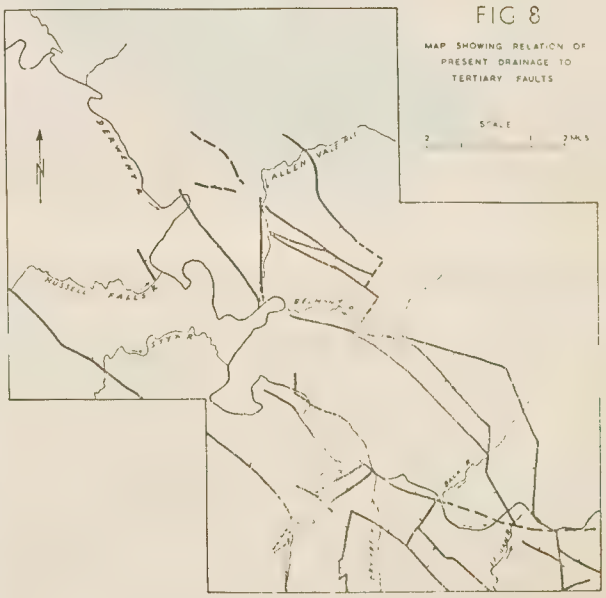
There are four possible interpretations to explain the 'high' between the "Glenora Low" and the 'Gleneg Low". They are:—

1. The basalts followed so soon after the block faulting that there was not sufficient time for the "Gleneg Lake" to silt up completely to its lip overflow level. In view of the upstream catchment the silting of such a depression would have been quite rapid.
2. The block faulting was protracted, commencing before the basalts but continuing almost contemporaneously with them so that a newly formed unfilled depression existed at the time of the outpouring of the basalts.
3. The block faulting is substantially older than the basalt, and the "Gleneg Low" was completely filled with lake sediments to spill point well before the time of the basalt. However the overflow river followed the shatter zone of the Askrigg Fault along which it was able to erode a narrow defile to a depth of below 300 feet above present sea level. With this new level the soft silts of the "Gleneg Low" suffered rapid erosion and were largely re-excavated and removed down the defile. Basalt in due course filled the "Gleneg Low" as well as the narrow defile connecting with the "Glenora Low".
4. There has been depression of the "Gleneg Low" with respect to the "Glenora Low" by post-basaltic movement. Of these four interpretations perhaps the third is the most probable. Nothing has been found in the area to suggest post-basaltic differential movements.

After each basalt flow, there were inevitable shallow undrained depressions caused by the irregularities of the basalt surface. These rapidly filled up with lacustrine sediments and cobbles of basalt and dolerite along the stream beds. Soils developed and forests grew before destruction by tuff showers or lava. Successive filling of the lakes and valley by basalt dislocated the drainage system with consequent development of a new system of drainage. The new courses tended to be along either side of the basalt field, as lateral streams. The diversison of the Derwent took place beyond Ouse. The river flowed on the south-west side of the basalt field as a lateral stream and joined the Glenora area which was still a comparatively broad low area. While cutting its course the Derwent meandered at 500 feet elevation and later at 350-400 feet elevation. The river at this latter elevation meandered over the Kenmore basalt tableland. Possibly at this time the narrow gap between Sugarloaf Hill and the southern edge of the basalt at Glenora was closed either by the basalts or the dolerite, or the northern extension of the Lawitta Fault still formed a higher scarp. Therefore the Derwent could not flow as a lateral stream in this part and was forced to cut a channel in the basalt itself. The Russell Falls River, which was not affected by the basalts, assisted in this work.

The filling of "Lake Glenora" diverted the Styx River to flow at a higher level as a lateral stream between the basalts and the Moogara dolerite plateau. The Styx River vigorously carved a course roughly parallel to its present course and pushed northwards until it joined the Derwent. The Allen Vale Rivulet occupied a position roughly parallel to its present course further east and progressively migrated to its present position and was assisted by the various creeks and the Belmont Rivulet. The courses of the Plenty River and Dry Creek were not affected to any degree by the basalt floods. These flowed down from the Moogara and Glen Fern plateau in a series of cascades and rapids bringing with them a lot of sediments which were deposited in the valley. The Derwent River assisted by all these rivers rapidly eroded the basalt floor in the New Norfolk area and has left remnants of basalts at a higher elevation, and flowed as a lateral stream on the north side of the basalt-filled valley.

Thus it is apparent from the map, Fig. 8, and the description given above that the drainage of the Derwent Valley in this part is controlled by the Tertiary structure. The resistant dolerite was also partially responsible for keeping the Derwent within the graben.



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GEOLOGY OF TASMANIA

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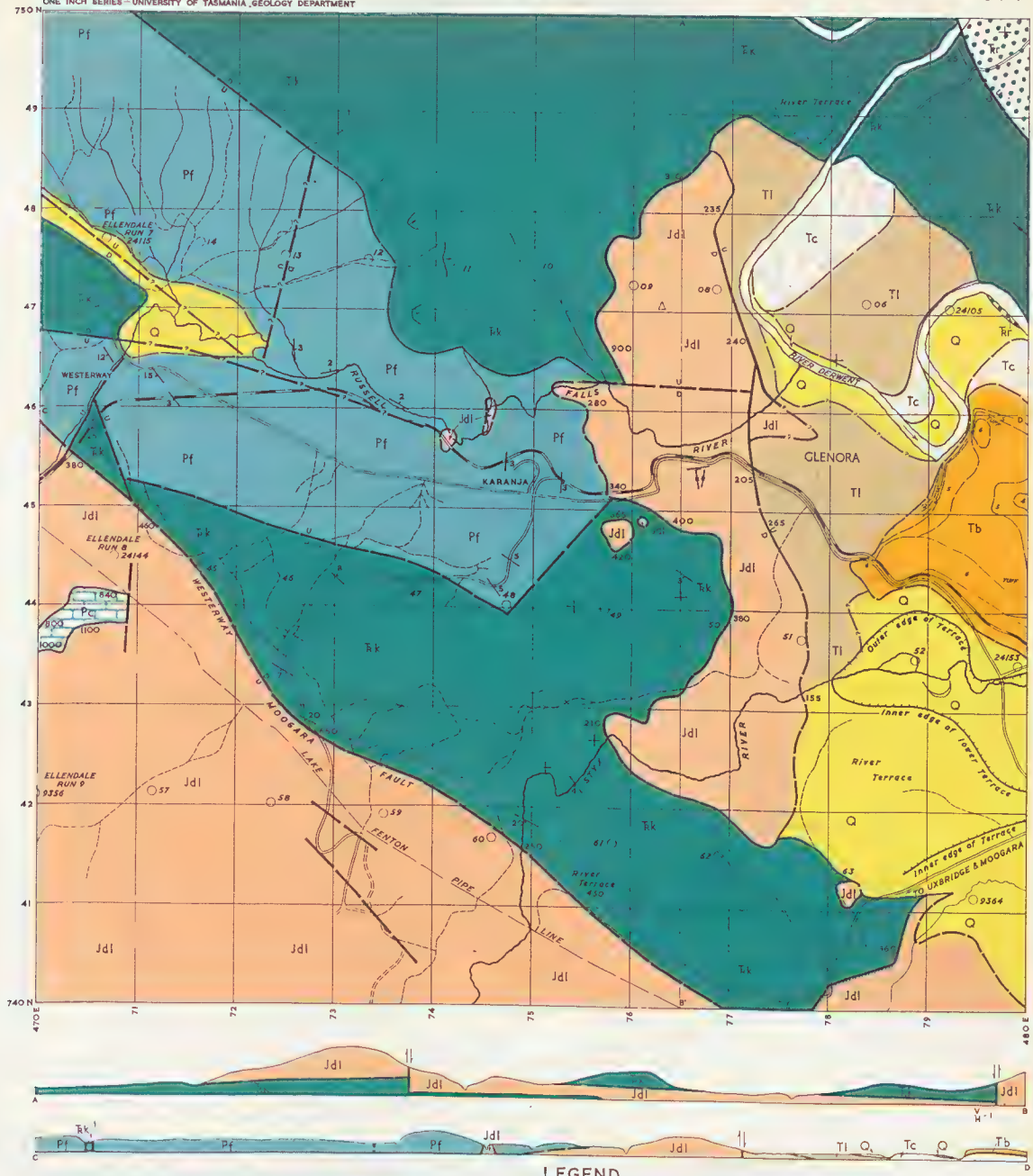
# GLENORA

4774




## LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT POSITION APPROXIMATE
- FAULT INFERRED
- FAULT CONCEALED
- FORMATION BOUNDARY

**Dolerite Boundaries**

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY
- EDGE OF RIVER TERRACE
- STRIKE AND DIP OF STRATA
- HORIZONTAL DIP
- VERTICAL JOINTS
- STRIKE AND DIP OF JOINTS
- ROAD
- RAILWAY LINE
- VEHICULAR TRACK
- FOOT TRACK

NUMBERS ON DOLERITE BOUNDARIES ARE TOPOGRAPHIC HEIGHTS.

NUMBERED LINES ON BASALT INDICATE FLOWS REFERRED TO IN TEXT.

**Quaternary System**

- Q — ALLUVIUM AND RIVER SEDIMENTS

**Tertiary System**

- Tl — LACUSTRINE SEDIMENTS
- Tc — CONGLOMERATES

**Triassic System**

- KNOCKLOFTY SANDSTONE AND SHALE
- Trf — ROSS SANDSTONE

**Permian System**

- Pf — FERNTREE FORMATION
- Pc — CASCADES GROUP

**IGNEOUS ROCKS**

**Tertiary System**

- Tb — BASALT

**Jurassic (?) System**

- Jdl — DOLERITE

KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. P.A.

Compilation from Aerial Photographs Trigonometric Station Control by courtesy Lands and Surveys Dept. and Hydro Electric Commission. Origin of co-ordinates 400,000 yds West and 1,800,000 yds. South of True Origin of Zone 7.

MAPPED BY M.A. ANANDALWAR 1957

SCALE

0 — 1 — 2 MILES

0 — 1 — 2 — 3 — 4 — 5,000 — 10,000 FEET

# GEOLOGY OF GLENORA

## SHEET 4774

### Physiography

The Westerway-Moogara plateau forms the main feature to the south and south-west of the sheet. Pre-basaltic "Lake Glenora" forms the basin bordered by the western end of the Kenmore Hill and Sugarloaf Hill. The Derwent River has developed entrenched meanders. The Styx River flows in the area as a lateral stream with prominent depositional flats.

### Stratigraphy

The Permian Ferntree Mudstone is exposed from Karanja to Westerway. The overlying Triassic rocks on the north side of Russell Falls River show an angular unconformity with the underlying rocks (475 • 746.4). A conglomerate bed at the base of the Knockiofty Formation is exposed in the same area. Tertiary lake sediments in the Glenora area include 30 feet of basal conglomerate and 150 to 200 feet of sandstones and claystones. Claystones in the Dobson Highway east of Glenora contain plant fossils.

### Structure

The Westerway-Moogara Fault forms the main structural feature and is exposed in the Styx Valley Road. The Meadowbank Fault and the Clarendon-Norton Fault define the Derwent Graben.

### References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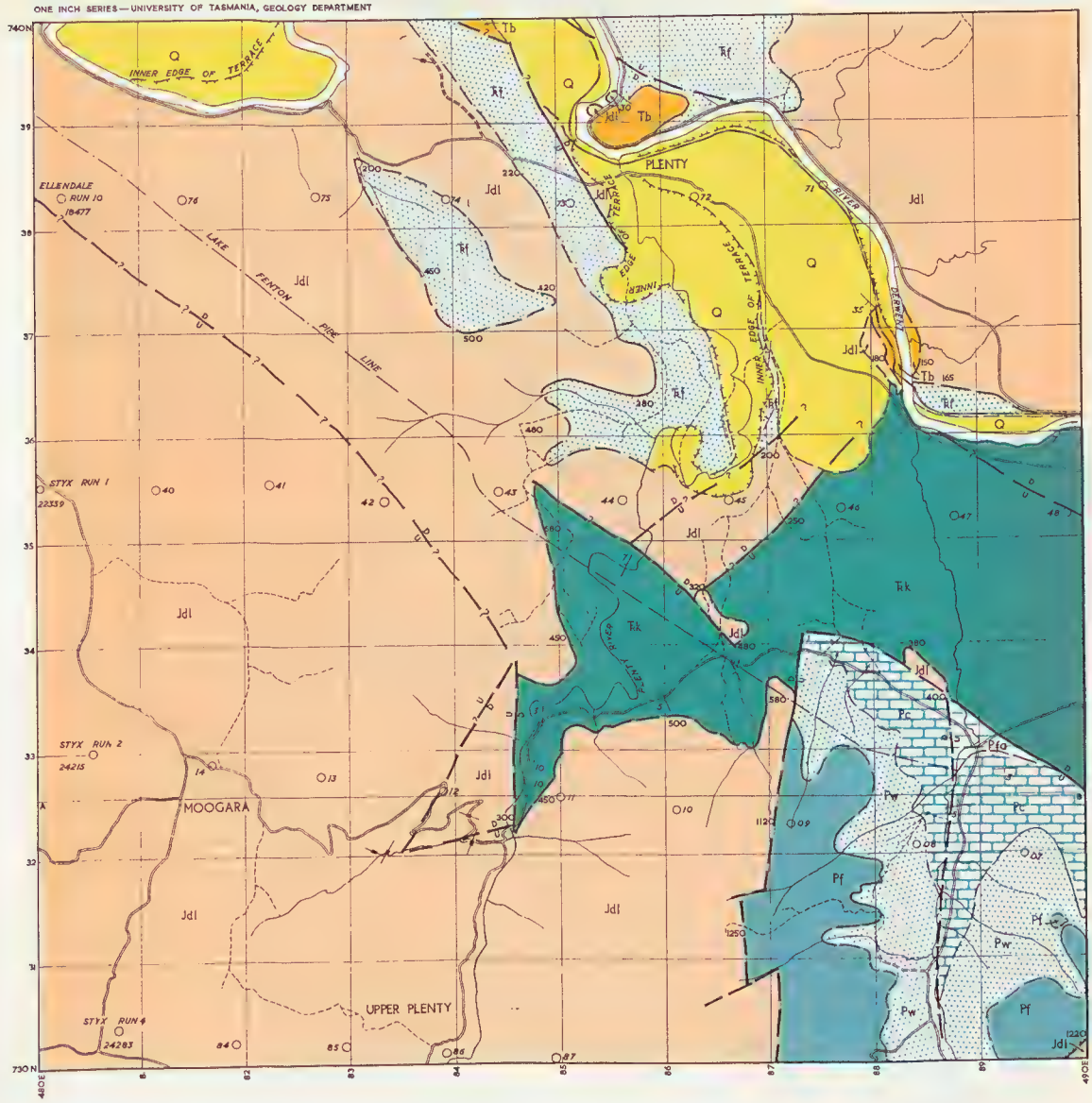
# PLENTY





## LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY
- FORMATION BOUNDARY POSITION APPROX.

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY
- VERTICAL JOINTS
- STRIKE AND DIP OF STRATA
- ROADS
- RAILWAY
- VEHICULAR TRACK
- TRACK
- PIPE LINE
- EDGE OF RIVER TERRACE

NUMBERS ON DOLERITE BOUNDARIES ARE TOPOGRAPHIC HEIGHTS

Quaternary System

- Q — ALLUVIUM AND RIVER SEDIMENTS

Triassic System

- Tf — FELDSPATHIC SANDSTONE
- Tk — KNOCKLOFTY SANDSTONE

Permian System

- Pf — FERNTREE FORMATION
- Pw — WOODBRIDGE GLACIAL FORMATION
- Pc — CASCADES GROUP
- Pfa — FAULKNER GROUP

IGNEOUS ROCKS

Tertiary System

- Tb — BASALT

Jurassic (?) System

- Jdl — DOLERITE

Compilation from aerial photographs.
Trigonometric Station Control by courtesy Forestry Commission.
Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

KEY MAP SHOWING MAGNETIC DECLINATIONS
SECULAR VARIATION 7 MINS. P.A

MAPPED BY M.A. ANANDALWAR 1957

SCALE

0 1 2 MILES
0 1 2 3 4 5000 10000 FEET

# GEOLOGY OF PLENTY

## SHEET 4873

### Physiography

Moogara plateau (the north-eastern face of which is a fault line scarp) forms the major feature rising to a height of 2000 feet. Quaternary depositional flats around Plenty are noteworthy.

### Stratigraphy

The spur south of the Glen Fern Road and Moogara Road junction exposes a complete sequence of Permian rocks from Bundella Mudstone to Ferntree Mudstone through the Faulkner and Cascades Groups. The Knocklofty Formation and "Feldspathic" Sandstone are exposed around Plenty.

### Structure

The Glen Fern Fault with a throw of 1800 feet is exposed at the Glen Fern-Moogara Road junction, bringing Bundella Mudstone and the Knocklofty Formation into contact. The Westerway and Moogara Faults form the continuation of the Glen Fern Fault. The Lawitta Fault has a throw of 500 feet towards the Derwent River. The Plenty Fault with a throw in the opposite direction delimits the Derwent Graben.

### References


Anand Alwar, M.A., 1960, Geology and Structure of the Middle Derwent Valley. **Pap. Roy. Soc. Tasm.** Vol. 94.

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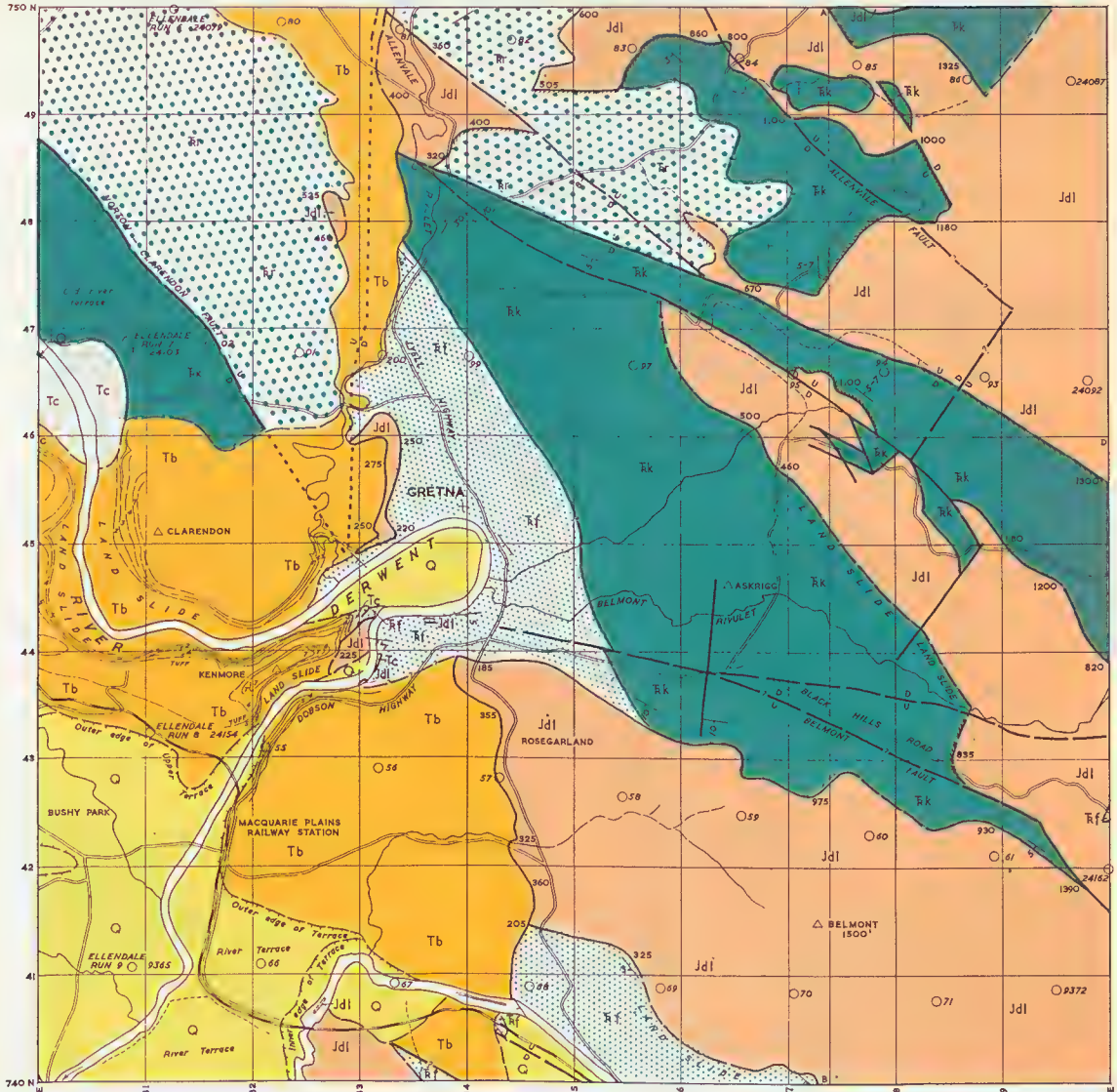
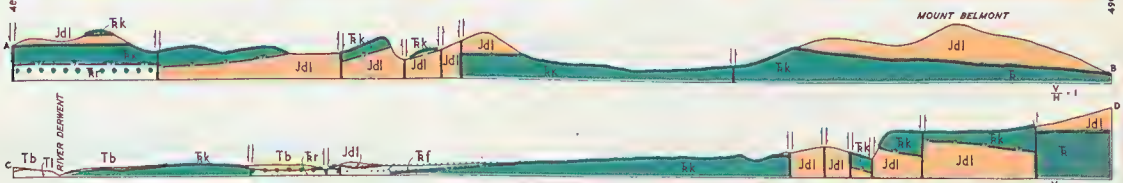
# MACQUARIE PLAINS






## LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT — POSITION APPROXIMATE
- FAULT INFERRED
- FAULT CONCEALED
- FORMATION BOUNDARY

**Dolerite Boundaries**

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARIES

- EDGE OF RIVER TERRACE
- STRIKE AND DIP OF STRATA
- HORIZONTAL DIP
- ROAD
- RAILWAY LINE
- VEHICULAR TRACK
- FOOT TRACK

NUMBERS ON DOLERITE BOUNDARIES ARE TOPOGRAPHIC HEIGHTS.
NUMBERED LINES ON BASALT INDICATE FLOWS REFERRED TO IN TEXT.

**Quaternary System**
- Q — ALLUVIUM AND RIVER SEDIMENTS

**Tertiary System**
- Tc — CONGLOMERATES

**Triassic System**
- Trf — FELDSPATHIC SANDSTONE FORMATION
- Trk — KNOCKLOFTY SANDSTONE AND SHALE
- Trr — ROSS SANDSTONE

**Permian System**
- Pf — FERNTREE FORMATION

**IGNEOUS ROCKS**

**Tertiary System**
- Tb — BASALT

**Jurassic (?) System**
- Jdl — DOLERITE

KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. P.A.

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Surveys Dept. and Hydro Electric Commission. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

MAPPED BY M. A. ANANDALWAR 1957

— SCALE —
0 1 2 3 4 5000 2 MILES 10,000 FEET

# GEOLOGY OF MACQUARIE PLAINS

## SHEET 4874

### Physiography

Mt. Belmont (dolerite) rises to a height of 1500 feet. The Black Hills range rises to 2000 feet further east. Kenmore forms a basaltic tableland in the middle of the Derwent Valley.

### Stratigraphy

The Triassic Ross, Knocklofty and "Feldspathic" Formations are exposed in the Clarendon and Gretna area. Tertiary lake sediments and basalts form the main feature of the Derwent Valley. A tuff bed at Kenmore is 75 feet thick and includes big boulders of dolerite.

### Petrology

East of Rose Garland at grid 484.6 • 743.3 near the base of the Belmont sill is an amygdaloidal dolerite with globules of mesostasis. Basalts in the Kenmore cliff carry brown opal with an abnormal specific gravity.

### Structure

The Magra, Askrigg and Belmont Faults form a system of step faults on the east side of the Derwent Graben. Clarendon and Mt. Belmont form horsts in this graben. A volcanic centre is suspected west of Allen Vale Rivulet.

### References


Anand Alwar, M.A., 1960, Geology and Structure of the Middle Derwent Valley. **Pap. Roy. Soc. Tasm.** Vol. 94.

Banks, M. R., 1955, Tertiary Fossil Forest at Macquarie Plains. **Tas. Nat.** Vol. 11, No. 3, pp. 1-11., (for earlier references).

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GEOLOGY OF TASMANIA

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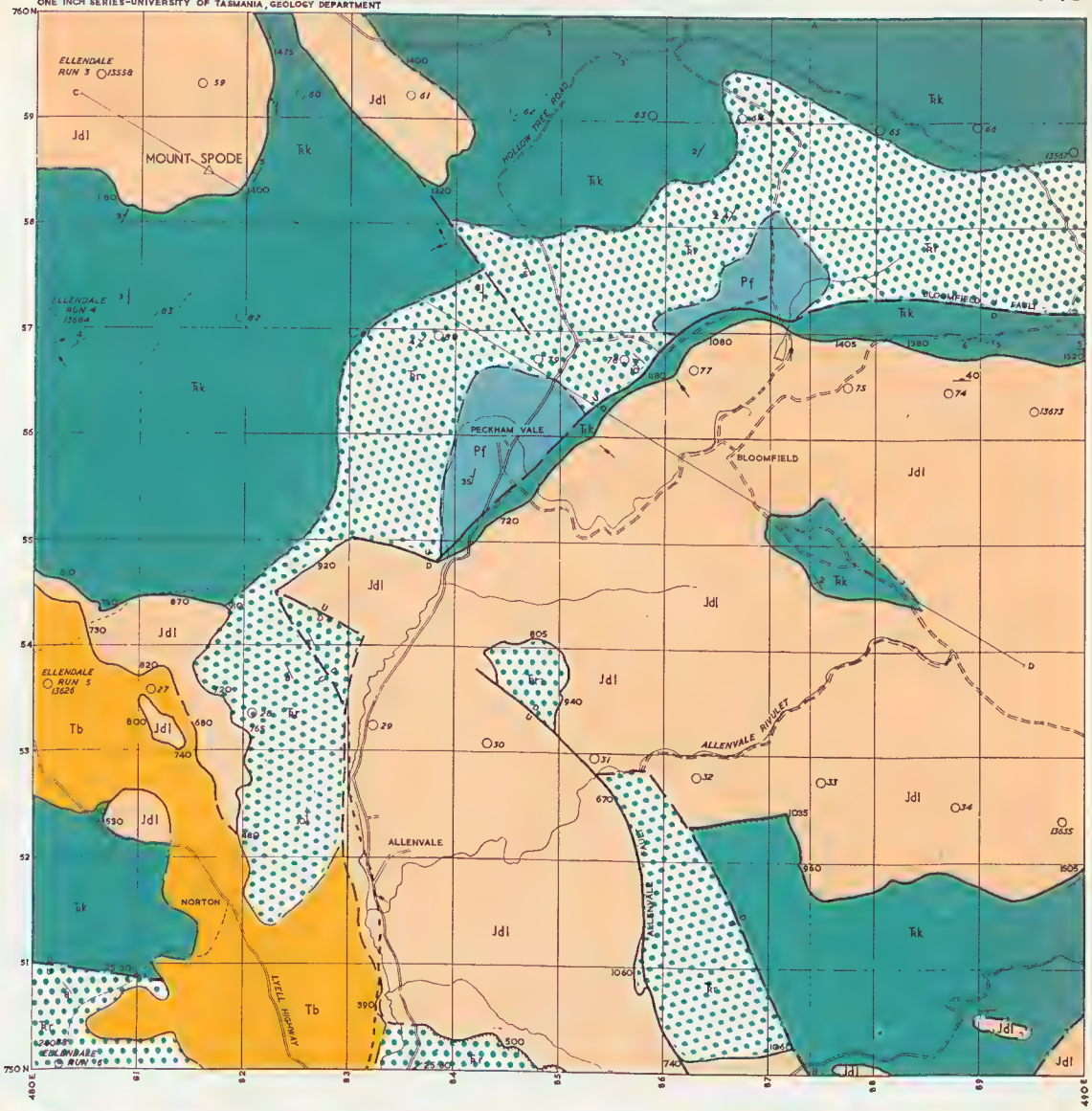
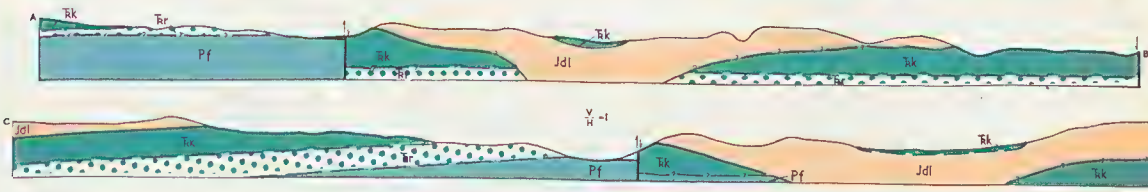
# MOUNT SPODE

4875




## LEGEND

- FAULT WITH DOWNTHROWN SIDE INDICATED
- FAULT CONCEALED
- FAULT POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY
- FORMATION BOUNDARY APPROXIMATE

Dolerite Boundaries

- CONCORDANT BOUNDARY
- DISCORDANT INTRUSIVE BOUNDARY

- VERTICAL JOINT
- STRIKE AND DIP OF JOINTS
- STRIKE AND DIP OF STRATA
- ROAD
- VEHICULAR TRACK
- FOOT TRACK

NUMBERS ON DOLERITE BOUNDARIES ARE TOPOGRAPHIC HEIGHTS

Triassic System

- Tk KNOCKLOFTY SANDSTONE AND SHALE
- Tr ROSS SANDSTONE

Permian System

- Pf FERNTREE FORMATION

IGNEOUS ROCKS

Tertiary System

- Tb BASALT

Jurassic(?)System

- Jdl DOLERITE

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Surveys Dept. and Hydro Electric Commission. Origin of co-ordingtes 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7.

MAPPED BY M.A. ANANDALWAR 1957

SCALE — 2 MILES — 0 1 2 3 4 5,000 10,000 FEET

KEY MAP SHOWING MAGNETIC DECLINATIONS SECULAR VARIATION 7 MINS. P.A.

# GEOLOGY OF MOUNT SPODE

## SHEET 4875

**Physiography**

Physiography is dominantly controlled by the structure and the complex dolerite intrusion. Mt. Spode. a dolerite mass, rises to a height of 1600 feet with Triassic rocks flanking the eastern and southern sides.

**Stratigraphy**

The sedimentary sequence includes the Permian, Ferntree Mudstone, overlain by Triassic Ross and Knocklofty Formations with conglomerate at the base of the Ross Sandstone. The conglomerate bed near the base of the Knocklofty Formation is of stratigraphic significance (488.4 • 755.8) Igneous rocks include Jurassic dolerite and Tertiary basalts.

**Petrology**

Granophyric differentiates of the Jurassic dolerite are seen east of Bloomfield at grid 490 • 754.5. Contact metamorphism of the dolerite due to Tertiary flows is seen west of Allen Vale homestead (483 • 751.9).

**Structure**

The Bloomfield area forms a centre of dolerite intrusion accompanied by cauldron subsidence. The Bloomfield Fault forms a partial ring fault with a throw of 1000 $\pm$ feet. Radial tensional faults and joints are present.

**References**

Anand Alwar, M.A., 1960, Geology and Structure of the Middle Derwent Valley. **Pap. Roy. Soc. Tasm.** Vol. 94.

# THE GEOLOGY OF THE FISHER RIVER AREA

By

R. J. Ford

*Geology Department, University of Tasmania*

(With one text figure and 1 coloured map).

## ABSTRACT

Folded Precambrian quartzites, phyllites and schists are unconformably overlain by Permian and Triassic sediments. Jurassic (?) dolerite occurs as a large transgressive sill-like intrusion into the Permian and Triassic rocks. Tertiary basalt occurs as a valley filling. The whole area is covered by scree and till with the development of terminal moraines in some areas.

## ACKNOWLEDGEMENTS

Acknowledgements are due to the Hydro-Electric Commission, for whom the work was originally done, for permission to publish this material; to Mr. M. R. Banks for helpful criticism and permission to use the Kansas Creek section and to D. Woolley and N. Ahmad for help in the field mapping.

## INTRODUCTION

During the summer of 1955-56 a geological survey was undertaken of the area defined by the co-ordinates 420E. 860N, 420E. 870N, 430E. 870N, 430E. 860N on the 4-mile map of Tasmania. The topography is rugged with elevations ranging from approximately 1400 feet in the valleys to 4400 feet on the Central Plateau. The area is drained by three main streams. The major stream is the Mersey River, flowing approximately from south to north along the western boundary. The Fisher River, flowing through a gorge from Lake Mackenzie on the Central Plateau passes along the northern part of the area, then swings to the north-west and joins the Mersey. It is the most important tributary of the Mersey in this area. The third river is the Little Fisher which flows off the Central Plateau in a general north-westerly direction through the south-eastern corner of the area, eventually connecting with the Fisher River. An important tributary of the Mersey River is the Fish River which flows east-west off the Central Plateau about one and a half miles south of the area of interest. However, some important observations were made in this river valley.

## STRATIGRAPHY

The stratigraphy of the area may be summarised as follows. The section is composite and the thicknesses given are only approximate because of lack of suitable outcrop. On account of the lack of continuous outcrop in the particular area studied, the available material has been combined with a section measured in Kansas Creek, north-west of Western Bluff. Here the lower parts of the Permian succession are exposed. This section is only four miles north of the Fisher River and is not regarded as having any significant differences in thickness from that projected on to the map although the conglomerate and sandstone phases of the basal formation appear to be more dominant further to the south. The detailed section for the Permian Group, from the base to Liffey inclusive, is quoted by kind permission of Mr. M. R. Banks who has measured the section in Kansas Creek, in detail. Correlation has been suggested between Permian and Triassic rocks mapped in this area with formations established by Wells (1957) and McKellar (1957). The main evidence for these correlations lies in the presence of the Liffey Group and the conglomerates in the Ferntree Group.

Quaternary System

Terrace materials 30'+
Till and Talus + 100' ±

Tertiary System

Basalt 200'

Jurassic System

Dolerite 600'-1000' (variable)

Triassic System

Knocklofty (?) Sandstone and Shale 600' (maximum)

Permian System

Ferntree Group 650' (maximum)
Woodbridge Glacial Formation 250' (approx.)

Liffey Group 127′

| | | |
|---|---|---|
| 23′ | 0″ | Gap |
| 5′ | 6″ | Carbonaceous siltstone |
| 11′ | 0″ | Gap |
| 87′ | 6″ | Interbedded, well-sorted quartz sandstone with cross bedding and thinly bedded micaceous and carbonaceous siltstones; basal 6″ of sandstone has quartz, some feldspar, heavy minerals visible and boulders up to 2″ in diameter. |

Golden Valley Group 214′

| | | |
|---|---|---|
| 26′ | 0″ | Dark grey, compact, brittle somewhat fissile siltstone with well rounded pebbles increasing towards the top (Macrae Mudstone). |
| 66′ | 0″ | Gap. |
| 15′ | 0″ | Alternate bands of dark grey siltstone and conglomerate with rounded pebbles and silty matrix. Beds about 15″ thick (Billopp Conglomerate). |
| 18′ | 0″ | Gap |
| 29′ | 0″ | Dark grey sandstone containing quartz, feldspar and mica. Fossils include *Dielasma, Keenia,* spiriferids and Aviculopectnidae. |
| 59′ | 0″ | Richly fossiliferous grey siltstone with numerous erratics. Impure limestone in parts. Erratics mainly quartzite and quartz mica schists. Fossils present include *Strophalosia* and Spiriferids, *Fenestella, Stenopora,* gastropods, pelecypods, ostracods, foraminifera including *Calcitornella, Ammodiscus* and *Hyperamminoides.* Gastropods include small euomphalids. *Eurydesma cordatum* is present but is rare and small. Bedding indistinct. |
| 1′ | 0″ | Impure limestone with erratics and spiriferids. |

Quamby Mudstone 66′+

| | | |
|---|---|---|
| 66′ | 0″ | Grey irregularly fissile fine siltstone with rare erratics and small carbonaceous markings. Bedding poorly defined. |

Basal conglomerate, sandstone and siltstone 45′ (max.)

| | | |
|---|---|---|
| 25′ | 0″ | Gap. |
| 8′ | 0″ | Quartzose conglomerate with variable amounts of boulders. |
| 2′ | 6″ | Siltstone. |
| 1′ | 6″ | Gap. |
| 1′ | 6″ | Dark grey sandstone. |
| 4′ | 6″ | Gap or sandy conglomerate. |
| 1′ | 6″ | Siltstone |

Precambrian System

Quartzites, phyllites and schists 10,000′+

**Precambrian**

The Precambrian rocks in this area consist of quartzites, slates, phyllites and schists. These rocks have been sub-divided into the Fisher and Howell Groups by Spry (1958).

South of the Fisher-Mersey junction the sequence consists of massive white to pinkish glassy quartzites dipping to the south. With the massive quartzites are more finely laminated quartzites containing mica flakes and incompetent beds of black and white quartzite. Interbedded with these quartzites are some dark thinly bedded phyllites. The quartzites show " ripple marks " on the bedding planes. These have probably been formed as a result of superimposed forces rather than an original sedimentary feature. The dark phyllites interbedded with the quartzite show two prominent lineations, one of these is on the bedding plane (or cleavage surface), and the other one cuts obliquely across the bedding. The thickness of these is about 3,000 feet.

Between 869N and 868N and apparently overlying the above rocks, the Precambrian rocks consist mainly of dark thinly-bedded phyllites and slates which have a banded appearance due to the alternation of black and white bedding laminae. The thickness of these varies in a manner characteristic of incompetent beds. These give way to massive white quartzites at approximately 868N. These appear to be about 2,000 feet thick.

South of 865N, the rocks consist of hard quartzites overlain by quartz-mica schists containing garnets. These are overlain by rocks consisting dominantly of glassy laminated quartzites. The laminae in the quartzites vary from one quarter of an inch to six inches in thickness. In these rocks a parting tends to develop parallel to the bedding, causing the formation of tabular scree material. The bedding appears as fine iron stained partings or as variations in texture, lustre, and colour in the massive rock.

Some of the quartzites contain bands of muscovite giving them a schistose appearance. Near the axial part of the synclinorium there is mainly contorted quartzite which further to the south becomes interbedded with garnet mica schists. The quartzites show much incompetent folding here particularly when micaceous bands are present. In some of the rock types well formed black garnets with crystal faces may reach a quarter of an inch in diameter. These occur in quartzitic and schistose rocks. The thicknesses cannot be determined

accurately because of complex folding and possible faulting. The total thickness appears to be at least 10,000 feet.

Some brecciated material occurs in the scree of the hillside near the phyllite-quartzite contact at 421E 868N, indicating a possible fault in this area.

Thin sections of samples of the Precambrian rocks show generally that the schists consist essentially of sheared irregular quartz grains, and layers of muscovite, often bent round small rounded crystals of garnet. In the incompetent beds the microscopic section shows small drag folds developed in the muscovite bands. These run through the quartzose part of the rock and preserve their form as small shears along which muscovite is developed.

### Permian System

The Permian rocks are found throughout the area but outcrop is poor hence a composite section has been compiled. The best section of the Permian occurs on the western slopes of Western Bluff along Kansas Creek which flows past the Tasmanian Board Mills mill. The beds below the Liffey Group have been called the Kansas Creek beds on the Department of Mines, Middlesex Sheet.

### Conglomerate

Th basal conglomerate overlies the Eldon Group under Western Bluff (see Middlesex Sheet). It is rather variable in composition. About one and a half miles south of here at about the 2,200 feet level, the conglomerate appears to have a clay matrix. Further south at about 2,500 feet a good exposure shows the more typical conglomerate as a very coarse conglomerate containing rounded tabular pebbles of quartzite up to two inches in diameter. Some schist fragments are also present indicating that the material has not been transported very far. Small chips appear to have been knocked off many of the pebbles. The pebbles are set in a sandy, angular, quartzose matrix with an average grain size of about 0.5 mm. to 1 mm. with some large fragments. Along the east bank of Snake Creek the rock is a pebbly siltstone, the matrix being finer and darker. Under Clumner Bluff, east of Dublin Plain, and in the outlier south of the basait, the basal formation is a white baked siliceous sandstone with some feldspathic material, larger pebbles not being as common as above. In the latter locality the remains of a crinoid column have been found. Unleached, the rock is iron stained. In the Fish River, south of the area the conglomerate is covered by other deposits. The maximum thickness of the conglomerate is about 45 feet. The conglomerate breaks down very readily to leave a loose scree of rounded quartzite pebbles on the ground surface.

### Quamby Mudstone

The conglomerate at Western Bluff, exposed in Kansas Creek, is overlain by a dense, dark-grey mudstone containing small quartz erratics and occasional larger pebbles. This may be equivalent to the Quamby Mudstone of McKellar and has been mapped as such. The Stockers Tillite is missing and its equivalent is probably the basal conglomerate. In the Fish River a similar type of mudstone low in the sequence contains occasional *Eurydesma*, bryozoa and some fossil wood fragments. The Quamby Mudstone contains occasional erratics. Here there are also calcareous nodules present.

A mudstone overlies the basal conglomerate at the 2450 foot level two and a half miles south-west from Kansas Creek. At this locality a band of angular quartzose sandstone, with some large pebbles, occurs. It is about 10 feet thick but does not appear to outcrop in any other locality. It occurs about 70 feet above the base of the Permian. The sediments overlying this are also sandy and micaceous, but may represent drift. Micaceous shales occur where some trees have been uprooted above the sandstone.

### Golden Valley Group

Where the Forestry Commission loop road crosses Kansas Creek on Western Bluff there is an outcrop about 30 feet thick of grey dense mudstone containing erratics and very rich in calcareous fossils, particularly brachiopods of which *Strophalosia* is important. Above this mudstone, large pebbles become very numerous leading to the formation of a conglomerate of large rounded quartzite erratics embedded in a matrix of very dark dense mudstone. This band is about five feet thick. Overlying this is about 150 feet of a dense dark-grey to black mudstone with occasional pebbles. These rocks are recorded as being equivalent to the Golden Valley Group. Dark mudstone is an approximately equivalent position in the Fish River contain pyrite nodules.

### Liffey Group

Overlying the Golden Valley Group is a band of prominent cliff-forming sandstone which belongs to the Liffey Group. The sandstones are orange coloured and may be leached white. The grainsize is uniform being about one mm. The rock is made up of angular fragments of quartz with lesser amounts of feldspar and occasional flakes of muscovite. Thin bedding laminae are present. Numerous carbonaceous remains are present in parts of the rock. Coarser bands are present in the rock and finer grained micaceous thinly bedded sandstones may also be present. This group may be 130 feet thick, but the only outcrop is in Kansas Creek and this is covered in part. Liffey Group rocks were not seen to crop out in the Fish River.

### Woodbridge Glacial Formation

The Woodbridge Glacial Formation overlies the Liffey Group and consists of grey and black shales, grey silty sandstone with pebble bands and some marly bands rich in fossils, e.g., brachiopods and bryozoa, particularly *Fenestella*. Massive, dirty feldspathic sandstones, containing brachiopods, occur. The thickness is about 250 feet.

### Ferntree Group

The Ferntree Group consists of dense dark to light grey massively bedded mudstones. Some of the mudstones are dark and featureless while others

are lighter in colour containing white markings giving the rock a spotted appearance. Small pebbles of slate and quartzite are present. Dark markings similar to those of the Ferntree rocks in the Hobart area, are common in the rocks of this area. A band of conglomerate occurs near the top of this group. It is very thin being only a few feet thick. The conglomerate consists of large pebbles of quartzite averaging one inch in diameter embedded in a ground mass of anguiar quartz fragments up to 2 mm. across. No matrix appears to be present. This member forms a prominent bench on the north-east limb of Clumner Bluff and also to the east of the Little Fisher Plain. This conglomerate may be equivalent to the Blackwood Conglomerate (McKellar, 1957). Four hundred feet below this to the east of the Little Fisher Plain is a 5-foot band of sandstone probably equivalent to the Palmer Sandstone. It is uniform in grainsize, about 1-2 mm., and contains large fragments of clear quartz. It is very hard. The base of the Triassic rocks occurs a few feet above the Blackwood Conglomerate and it is not known what rock types occur immediately below the Triassic sandstones.

**Triassic System**

*Knocklofty (?) Sandstone and Shale*

The maximum thickness of this formation is approximately 600 feet. It consists of a fine to very fine-grained thinly-bedded quartzo-feldspathic sandstone. It is generally yellowish in colour and shows cross-bedding on a limited scale. The bedding planes are covered by flakes of muscovite similar to those in the shales in the Hobart area. The remains of plants occur in the sandstone and shale bands. The Triassic occurs in the Little Fisher River, Fish River and under Clumner Bluff. It also occurs under Western Bluff.

**Jurassic System**

*Dolerite*

The dolerite covers the higher parts as a sill-like intrusion. It is mainly medium to coarse grained in texture and quite often shows platy jointing. This is particularly evident in the talus of the Devils Gullet and also under Clumner Bluff.

**Tertiary System**

*Basalt*

The basalt does not show obvious columnar jointing. The rock in the hand specimen is dense, dark, and fine-grained, but is not tachylytic in nature. Vesicular basalt and pumice is common showing the presence of at least two flows. Associated with the basalt are a few boulders of a very coarse breccia of quartzite fragments. These occur on the northern limb of the flow. They may represent original rubble picked up and cemented by the influence of material associated with the flow.

**Quaternary System**

*Pleistocene*

*Till and Moraine.*—A thin veneer of till covers the surface of the Permian and Precambrian rock on the hills south of 868N. Along the Mersey Valley erratics of dolerite boulders occur on the Precambrian in very unstable positions. The distribution of till is mainly in front of the north-west face of Clumner Bluff. It is not very thick (50 feet maximum) and consists of rounded dolerite pebbles in a sandy and clay matrix. The deposits in the Mersey Valley are probably of glacial origin, but their depth is unknown. The greatest thickness of till in the area is in the Little Fisher Valley where the maximum thickness is probably less than 200 feet. Material of glacial origin does not pass beyond the junction of the Little Fisher and Fisher Rivers. Some very big erratics of dolerite occur in the Little Fisher Valley. Many of these have a volume of at least 4,000 cubic feet. The Little Fisher has been incised in till revealing at least 50 feet of this material. Some of the finer material has a tendency to bedding; hence this may be of fluvioglacial origin.

The Little Fisher Plain consists of dolerite and quartzite pebbles embedded in a fine clay ground mass. This probably represents an old lake and fluvioglacial deposits built up behind the terminal moraines. Howells Plain in the Mersey Valley probably had a similar origin being deposited behind the Mersey Falls. In the Fish River, fluvioglacial material occurs in parts covering the Permian rocks. This is over 100 feet thick and occurs in pockets apparently gouged in the Permian rocks. Varves are also present here, at approximately 421E. 856N.

**Recent**

A mantle of dolerite scree covers the face of the Central Plateau throughout the area. Very few sedimentary blocks appear in this talus. On the steeper slopes of Clumner Bluff, this would not be greater than 50 feet. The average size of the blocks would be about one cubic yard. In the Devil's Gullet the blocks are very much larger. The blocks consist of fragments of large dolerite columns. The thickness of scree in this area is much greater than above. The scree slopes along the eastern edge of the Little Fisher River appear to be quite thick. Some of the talus may be older than Recent because of the great amount present and the fact that the dolerite must have been exposed to weathering in the early Tertiary. In this case the earlier talus would have been modified by the glaciation to become part of the till.

Terraces due to fluvial action occur in the lower Fisher River area. The terrace materials here show imbricate structure.

## GEOLOGICAL STRUCTURE

Due to a heavy cover of scree the structure is not always apparent. Because of the availability of a reliable contour map it was found expedient to build up the map by extrapolating, using the strike line principle, from known outcrops.

The geological structure of the area may be covered by the following groups:

1. Structures in Precambrian rocks.
2. Structures in Permian and Triassic rocks.
3. Intrusive structures.
4. Post intrusive faulting and jointing.

### Structures in Precambrian rocks

Assuming that the phyllites and quartiztes represent original compositional variations, and layering now visible in the quartzite is due to bedding, then the main structural feature of the Precambrian rocks is very tight folding, with steeply dipping limbs. There are several orders of folding. Reversals of dip quite often occur along the strike, particularly in the incompetent slates and phyllites. The fold axes strike generally in an east-south-east direction and cleavage-bedding relations in the Mersey Valley near 865N indicate that the beds are not overturned. The general structure would appear to be a synclinorium with its axis in the vicinity of 864N with other folds developed in the limbs.

Along the Fisher River the dips are consistently in a southerly direction, the river itself following the strike of the rocks. South from the Mersey-Fisher junction the dips are southerly with a consistent dip reversal near 868N. This represents a large syncline which is however probably only a part of the larger structure. This structure is persistent because a traverse in square 423E. 867N shows a similar reversal along a direction consistent with this axis.

The complementary anticline occurs between 867N and 866N. This structure could not be located as accurately as would be desired because of the lack of outcrop. The axis passes near the basalt which fills a valley, originally carved in a limb or even near the core of this anticline. There is a prominent valley bearing approximately along the axis of this anticline.

South from this axis the dips along the River Mersey are generally southerly. However, on the hilltops, the dips are not as regular and many reversals, due to minor structures, are present. Minor structures near 865N indicate the existence of an anticline to the north and a syncline to the south. Near 8623N the axial portion of the major synclinorium is exposed. This is characterised by the presence of highly contorted and broken rocks. From here southwards the dip trends are to the north, the reversals being due to smaller structures. The southern limb of the synclinorium gradually disappears to the south, becoming covered by Permian rocks and Pleistocene (?) fluvioglacial material on Howell's Plains. The folds appear to pitch towards the east from cleavage-bedding relationships.

### Structures in Permian and Triassic Rocks

These rocks rest on the Precambrian with angular unconformity. The formations have the same attitude as the surface of the unconformity, dipping at a low angle (approximately two degrees) to the south-east. The rocks do not outcrop extensively due to their being covered by till and talus. They are probably broken by small faults but these are not apparent and overall probably not important because the outcrop agrees well with the reconstruction using strike lines. Some of the joint directions well developed in the dolerite are continued as stream channels off the plateau but this may represent a case of superimposed drainage. In the Devil's Gullet, these rocks are transgressed by the dolerite.

### Intrusive Structures

The Jurassic (?) dolerite forms a cap rock above 3600 feet throughout the area. The dolerite forms the main mass of the Central Plateau of Tasmania. It occurs in the main as a sill-like intrusion into the Permian and Triassic sediments. The thickness of the dolerite varies from 600 to 1,000 feet as measured on the fringes of the intrusion. The general form of the intrusion is that of a sill, but in detail the base of the dolerite is strongly transgressive. Thus on Western Bluff the base of the dolerite occurs at approximately 4,200 feet, overlying Triassic sediments. On going south from Western Bluff towards the Devil's Gullet the base of the dolerite becomes progressively lower to 3,200 feet on the northern edge of the Fisher Valley. The dolerite thus cuts out the Triassic between the Fisher River and Western Bluff. South of the Devil's Gullet on the eastern edge of the Little Fisher Valley the dolerite transgresses the Triassic rocks. On the air photographs (Mersey Run 3, no. 19) the bench representing the Triassic can be easily seen being transgressed by the dolerite. From south to north on the eastern edge of the Little Fisher River the base of the dolerite falls from about 3,800 feet to less than 3,200 feet on the southern edge of the Fisher Valley. Thus no Triassic sediments would be expected to occur in the Devil's Gullet. The dolerite in the Devil's Gullet is also strongly transgressive. The first dolerite occurring in situ in the Gullet is only a few hundred feet above the last Precambrian outcrop at about 2,100 feet, hence some hundreds of feet of Permian rocks have been transgressed. In this area the form of the dolerite intrusion would be that of a shallow inverted cone with the dolerite being transgressive in form outwards from the centre (cf. Carey (1958)). The dolerite appears to be more truly sill-like on Clumner Bluff and rises to the south in common with the dolerite south of the Fisher River. The dolerite is all part of the same continuous mass being highly dissected by the major streams. The base of the dolerite in the Fisher River appears to dip approximately 600 feet per mile in an easterly direction. The dolerite in the Fish River appears to have the same attitude but in the upper reaches of the Little Fisher Valley which is immediately east of the Fish Valley the dolerite base is higher. As no obvious faults of large throw cut the dolerite between these localities it would appear that the base of the dolerite must undulate somewhat.

The small area of basalt shown on the map has an important relationship with the Precambrian rocks. The basalt probably occurs as a valley filling, because of its outcrop to contour relationship. Its relation with the basalt to the west is not certain. No basalt occurs east of the creek flowing north from the Dublin Plain, although occasional pebbles of basalt may occur to this creek. The rock in situ is apparently much less widely distributed. To the west the basalt does not appear to have any connection with that west of the Mersey. No sign of basalt can be seen in the Mersey Valley. The southerly boundary of the basalt along 422E is in a saddle, the southern side of which is in Precambrian rocks and the northern side in basalt. One can ascend the northern side of the saddle for at least 300 feet and cross basalt all the way. On top of the hill near 867N. 422E the basalt merges in with

the flat top of the hill, the maximum elevation of the basalt relative to this surface being about 20 feet. The basalt rises in a series of benches which may represent various flows, the heights being about 20 feet. These upper benches are certainly not due to landsliding, because they are persistent and do not have the characteristic arcuate shape of landslips. The basalt on the eastern edge rises abruptly from about the 200 feet contour above Dublin Plain. Below this level the surface is hummocky, and springs are present draining into Dublin Plain. To the west the basalt appears to be in situ to about 100 feet below the saddle. Below this the hummocky surface is again apparent probably indicating landslides but no springs were seen. This may indicate that the base of the basalt slopes eastwards. No basalt was found outcropping on the Mersey River, only Precambrian being found here. If a pre-basalt valley did extend to the west it has now been undercut by the present Mersey Valley.

### Post-intrusive Faulting and Jointing

Although no post-intrusive faulting has been established in the area a feature of the map is the large number of linear structures which have been recognised and plotted. Many of these persist for some miles across the dolerite and can be observed in the underlying sediments; however no measurable displacement of beds has been observed on them. For example one prominent linear is responsible for a creek west of the Little Fisher plain, but the floor of the creek is made of solid Permian mudstones. East of the same area a prominent linear has caused the formation of a creek, but the sediments exposed here are undisturbed. Prominent directions on the north and south sides of the Devil's Gullet may be faults, but the base of the Permian does not appear to be displaced by them. A very distinct linear occurs east of Western Bluff, running approximately north and south and has been responsible for the formation of Marakoopa Creek to the north and Snake Creek to the south. Once again the base of the Permian is not noticeably displaced. Many of these linears on the surface of the Central Plateau are filled with superficial deposits. The linears in the Precambrian may be faults. It is hard to prove these because the rocks are generally highly contorted in this area. The dolerite on the plateau is very strongly jointed. Joints run in many directions, but the most prominent ones tend to have the following trends: north-west, north-east, north and east.

## PHYSIOGRAPHY

The area has a rugged topography due to the action of glacial and fluvial agents. Several levels may be recognised in the area. These are:

*a.* Pre-Permian surface;
*b.* Floor of the Tertiary basalt;
*c.* Surface of the Central Plateau.

### Pre-Permian Surface

The Pre-Permian surface, representing the unconformity between Permian and Precambrian rocks, is exposed between the Mersey River and the Western Tiers as a result of removal of overlying Permian sediments. The surface has now been dissected by the Fisher and Mersey River valleys. The Little Fisher valley in part has also been cut through this surface. Between the Permian basal outlier and Clumner Bluff, the surface has also been gouged slightly by glaciation. It would then appear that the surface has not been exposed for very long. It was also not extensively covered with ice because of the lack of dolerite erratics north of the Fisher River. It might be expected that the dip to the north-east may have been caused by recent erosion, but the basal Permian sediments also have a similar orientation which is not due to erosion. Since this surface has approximately the same attitude as the basal Permian sediments there is no reason to assume it has been very much modified by erosion since its exposure in this area. The flat-topped hills north and south of the Fisher junction are part of this surface. However from this area the surface has a low angle of dip north-eastwards thus it falls approximately 100 feet per mile from the Fisher junction towards the Tasmanian Board Mills camp, west of Western Bluff. The true dip of this surface is no more than two degrees in an east-south-easterly direction. The attitude of this surface beneath the dolerite may not be the same as indicated above, depending on the origin of its dip. The attitude could be due to:

*a.* Permian peneplanation.
*b.* Disruption due to faulting.

*(a) Permian Peneplanation*

While the surface itself has a general perfection, in detail it can be quite hummocky in parts, suggestive of *roches moutonnées* caused by a pre-depositional glaciation. However, the Permian sediments deposited on this are conglomeratic rather than tillitic in most cases and occasional marine fossils (e.g. *Eurydesma*) occur low in the sequence suggesting some marine action at least, in the formation of the surface. Thus the surface may represent a surface of marine erosion with the source of the sediments to the west from a glaciated area; the area to the east being the basin of deposition of Permian sediments.

*(b) Disruption due to faulting*

The dip of the surface could be due to tilting associated with epeirogenic movements or faulting. The variation in attitude across the Fisher River would suggest a fault approximately along this line. No reliable positive proof exists of a fault through the Precambrian rocks in this area. A tilted fault block as a result of pre- or post-dolerite faulting somewhere in the plateau or to the west of the area may have caused the tilt.

It would appear that the first proposition is the best explanation although epeirogenic tilting may have had some influence.

### Floor of Basalt

It is not certain which is the direction of dip of the basalt floor. Prominent seepages flow east towards Dublin Plain, but the remainder of the basalt flows are to the west (Spry, 1958), hence the main affinities are in a westerly direction. It would then appear that this basalt originally flowed in from the west and the remaining patch

seen now, fills the divide between a stream flowing into the Mersey and an old channel draining north-east towards the Little Fisher River. The base of the basalt appears to be about 150 feet below the existing saddle. The southern limb of the basalt dips steeply north and the northern limb dips about 50 degrees south.

**Central Plateau**

The plateau consists mainly of dolerite and is of an undulating nature with local areas of fairly sharp relief. The north-west corner of the plateau is saucer-shaped with the highest areas on the rim. This form is suggestive of the presence of a continental ice cap on the plateau (*cf.* Greenland). The ice has scooped out the rock near the less resistant joint directions, and many rock basin lakes and moraine dammed lakes due to small mounds of morainal material, have been formed. The movement of ice on this surface must have been essentially south-east away from Western Bluff. Ice movements in detail have been shown by Jennings and Ahmad (1957). Small spillover glaciers are suggested by the topography each side of the Devil's Gullet. The edge of the plateau in the vicinity of the Little Fisher valley has many places where small glaciers have spilled over. South-west of Clumner Bluff, a small glacial valley shows ice movement in the north-westerly direction. The persistence of the scarp of the Central Plateau does not suggest that the ice flowed over the edge on a large scale, but was confined to certain areas. A *roche moutonnée* and striations are present in the small valley south-west of Clumner Bluff.

A prominent feature of the edge of the plateau in this area is the Devil's Gullet, a gorge approximately 1,800 feet deep through which passes the Fisher River. It would appear that originally a small stream passed along this course then during the glaciation a glacier may have begun to enlarge the valley by removing the dolerite. The glacier then melted and the remaining erosion was carried out by the post-glacial Fisher River. A section across the Fisher shows that the river has cut its course in a small part of a larger valley indicating that the Fisher was probably originally a misfit river cut in a broad glacial valley. The river as it exists today is youthful and is controlled largely by the structure of the Precambrian rocks, and shows no signs of glacial action. The section does not show any sign of a U-valley but this may be due to the fact that the valley is now choked with large blocks of dolerite scree. By the end of the glaciation, the dolerite and most of the Permian sediments would have been removed leaving the river to cut through Precambrian rocks controlled by the structure, during post-glacial times. The Fisher River has a very steep V-valley and tortuous course from the Devil's Gullet to the Mersey River. Along its course terraces are present, probably formed as a result of redistribution of scree, and glacial material. Material in these shows imbricate structure near the Mersey River.

**Pleistocene Glaciation**

The distribution of glacial features is shown in Figure 1. The presence of till, dolerite erratics, and large boulders often perched in unstable places shows that the area has been glaciated. The Little Fisher Valley is the largest glacial feature in this square. The valley has a contour distribution characteristic of a U-valley. Glaciers moved into the Little Fisher Valley through numerous small valleys off the plateau. Ice moved into this valley from the west, east and south and a fairly large glacier moved northwards along the valley. Till occurs in the Little Fisher Valley as far as the Fisher River. Lineations in the till to the east of Dublin Plain in the Little Fisher Valley are probably due to glaciation. The glacier flowed as far as the junction of the Fisher River beyond which till is absent. Two, and possibly three, terminal moraines occur at the northern end of the Little Fisher Plain marking the retreat stage of the glaciation. A small moraine occurs on the edge of the Plateau near 4295E. 8645N. This is responsible for the damming of a small lake further to the east. The water from this lake seeps through the moraine to form the creek flowing westwards down the Tiers. There is no evidence of glaciation north of the Fisher River because here the Pre-Permian surface is laid bare, apparently unmodied and no dolerite erratics exist. In some places one may find rounded quartzite pebbles weathered from the overlying Permian rocks. In comparing the Fisher and Little Fisher rivers it can be seen from the map that the Little Fisher is a misfit stream whereas the Fisher has its own characteristic youthful valley.

The material south and south-west of Dublin Plain has been probably deposited by ice moving north-west from the scarp bearing north-east from Clumner Bluff. The Pre-Permian surface has been gouged by Pleistocene glacial movement. The limit of the ice is shown on the map by the distribution of till. Dublin Plain probably represents outwash from this glacier, flowing into the Little Fisher Valley. The actual divide between the two streams, in the valley running south-west from Dublin Plain, is a ridge of poorly sorted dolerite boulders having the form of a terminal moraine. North-east of this is a small circular lake in a swampy area. This could well be a kettle hole. Material nearer the Mersey River than the divide appears also to be another terminal moraine. This part of the valley has a distinct hanging valley relationship with the Mersey Valley suggesting movement into the latter. The Mersey Valley has the characteristics of a glacial valley, with truncated spurs, extending northwards as far as its junction with the Fisher River. Thus it would appear that a sheet of ice moving north-west off the Tiers gouged the Pre-Permian surface at the foot of the Tiers and developed a piedmont type of glacier which tended to spill excess ice into the Mersey valley via the valley south-west of Dublin Plain. Outwash from this glacier probably caused the formation of Dublin Plain.

The Fish River south of the area occupies the valley of a glacier which flowed from east to west into the Mersey and has since been deepened by the river in the soft Permian rocks. Ice moved south from the Clumner Bluff part of the area (Jennings and Ahmad 1957) into this valley and also from the south-east higher on the plateau. The mouth of the Fish where it enters the Mersey is in an alluvial fan former by redistribution of glacial and Permian sediments from higher up the valley. Till and varves occur extensively, overlying Permian sediments in the Fish River.

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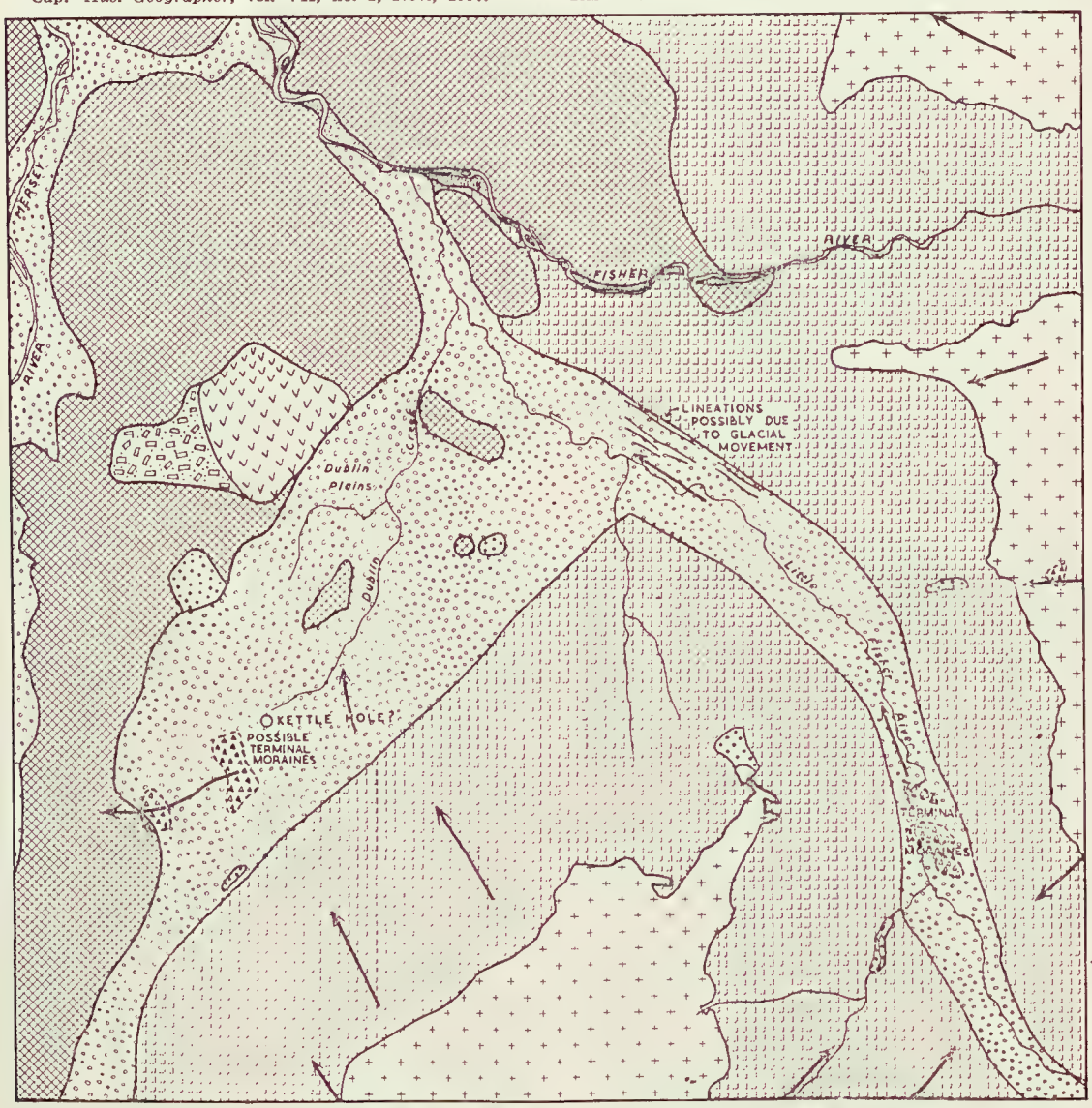
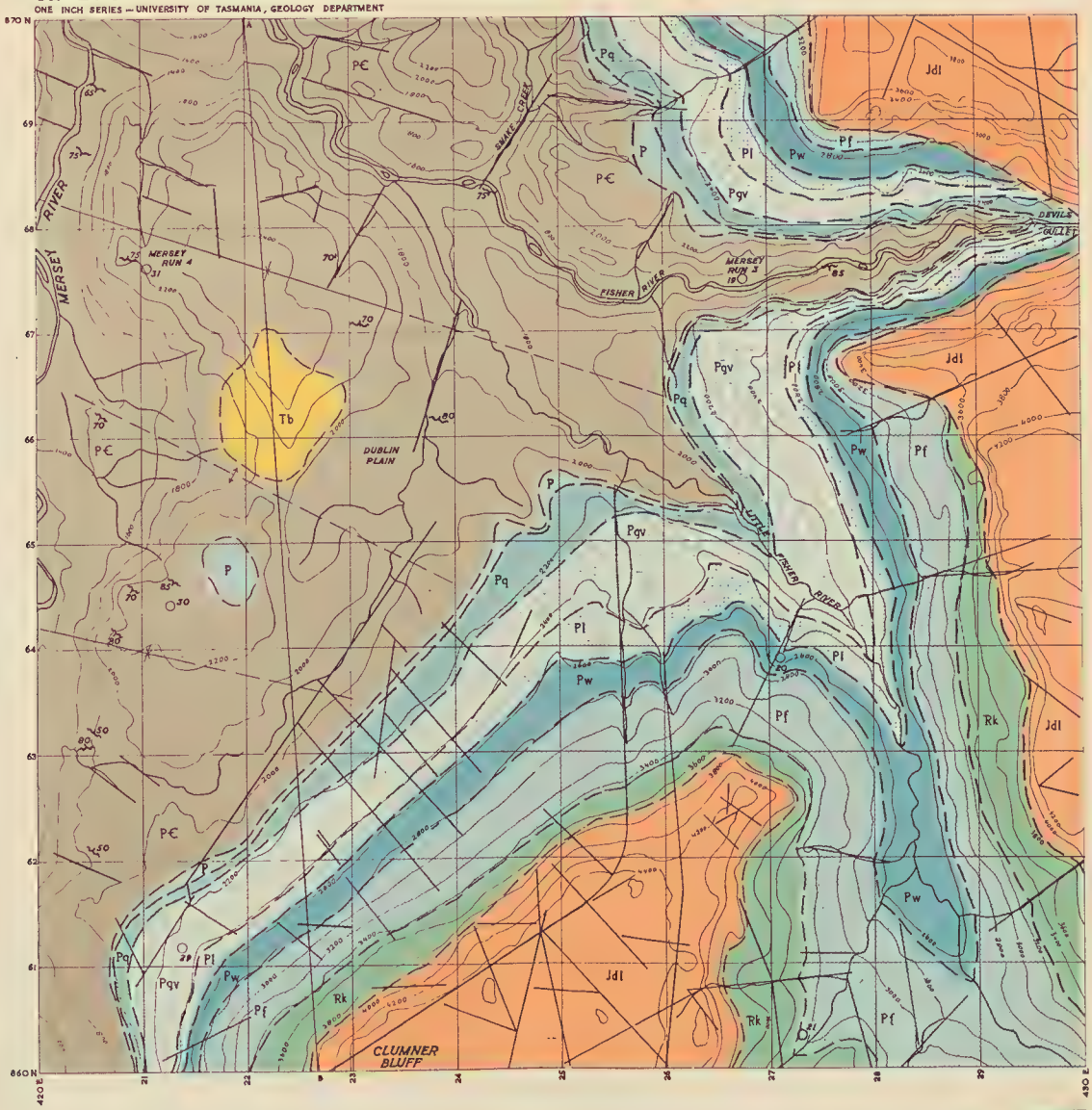
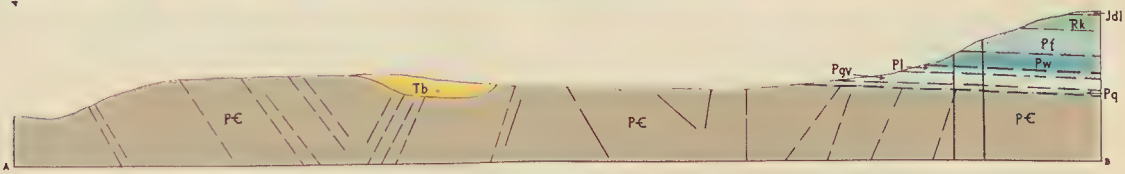



**Fig 1 GLACIAL FEATURES OF FISHER RIVER AREA**

# FISHER RIVER






## LEGEND

- LINEAR
- FORMATION BOUNDARY INTERPRETED
- ANTICLINAL AXIS
- SYNCLINAL AXIS
- VARIABLE DIP

IGNEOUS ROCKS

Tertiary System

- Tb BASALT

Jurassic(?) System

- Jdl DOLERITE

Triassic System

- Rk KNOCKLOFTY SANDSTONE AND SHALE

Permian System

- Pf FERNTREE GROUP
- Pw WOODBRIDGE GLACIAL FORMATION
- Pl LIFFEY GROUP
- Pgv GOLDEN VALLEY GROUP
- Pq QUAMBY MUDSTONE
- P CONGLOMERATE

Precambrian System

- PC QUARTZITES, PHYLLITES AND SCHIST

Compilation from Aerial Photographs. Trigonometric Station Control by courtesy Lands and Surveys Department. Origin of co-ordinates 400,000 yds. West and 1,800,000 yds. South of True Origin of Zone 7 of the International Grid.

*MAPPED AND COMPILED BY*
*R.J. FORD 1956*

*KEY MAP SHOWING MAGNETIC DECLINATIONS*
*SECULAR VARIATION 7 MINS. PER ANNUM*

SCALE

0 1 2 3 4 5,000 — 2 MILES — 10,000 FEET

# GEOLOGY OF FISHER RIVER AREA

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## 2. STRATIGRAPHIC TABLE:

| SYSTEM | GROUP | FORMATION | ROCK TYPE | THICKNESS |
|---|---|---|---|---|
| | | | **GLACIATION AND EROSION** | |
| Tertiary | | | Basalt flow filling old valley | 200′+ |
| | | | **STRONG EPEIROGENY AND FAULTING PENEPLANATION AND UNCONFORMITY** | |
| Jurassic ? | | | Dolerite sills | 600′+ |
| Triassic | | Knocklofty shale | Yellow fine grained well-sorted quartzose sandstone and micaceous shales. Some carbonaceous remains. | 400′+ |
| | | | **DISCONFORMITY** | |
| | Ferntree | | Dark mudstone with some erratics and lands of conglomerate and mudstone | approx. 650′ |
| Permian | Woodbridge | | Dark mudstones and sandstones with Brachiopods and Bryozoa | approx. 250′ |
| | Liffey | | Massive cliff-forming fine grained quartzo-feldspathic sandstones with carbonaceous markings | approx. 130′ |
| | Golden Valley | | Dark mudstone with occasional bands of erratics. Calcareous brachiopod fossils in a marl | approx. 185′ |
| | Quamby | | Massive dense dark shales with small quartz erratics. Occasional larger ones present. | approx. 100′ |
| | | | Conglomerate | 30′ |
| | | | **UNCONFORMITY** | |
| Precambrian | | | Quartzites schists and phyllites. Tightly folded | 10,000′+ |

## 3. IMPORTANT LOCALITIES:

Terminal Moraines: 428500E.862250N 429500E.864750N

# THE DUNDAS GROUP IN THE QUEENSTOWN AREA

By

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(With 1 Plate and 4 Text Figures)

## ABSTRACT

Reconnaissance geological surveys of the Dundas Group in the Queenstown area reveal that the sequence contains a suite of volcanic rocks including potassic rhyolites, quartz keratophyres, andesites, basalts and associated pyroclastics in additon to the sedimentary rocks, which are mainly paraconglomerates, greywacke sandstones and slates. The potassic rhyolites are confined to a narrow zone between Mt. Sedgwick and South Darwin and are flanked by lavas which vary from rhyolites to basalts but which generally contain a relatively high soda content. Viewing the West Coast as a whole this variable zone has a western limit beyond which the lavas are mainly of basic type and commonly spilitic.

The rock types which make up the Darwin Granite body are briefly described and it is noted that chemically they resemble members of the volcanic suite. The age of the granite is verified as pre-Junee Group.

It is suggested that the formation names previously proposed for the Dundas Group in this area are invalid.

## INTRODUCTION

Geologists have been attracted to the Queenstown area ever since gold was first discovered there in 1883 by a prospecting syndicate. The clearing of the thick rain forest and the development of the associated copper deposits that followed the initial discovery soon revealed the complexity of the local geology, which became the subject of numerous technical reports. Of the scientists who visited the field in its early years, Professor J. W. Gregory was the first to extend his survey beyond the mine leases and his geological map published in 1905 remained the principal reference for many years. The Tasmanian Mines Department gradually developed its activities on the Lyell and the nearby Jukes and Darwin fields and by the middle 1930's an approximate picture of the geology had been obtained. However, not until Bradley began his work in 1950-51 had any attempt been made to produce a general geological map of this part of the West Coast, despite its obvious economic importance.

This pioneer work was followed in 1954-56 by a more detailed survey of the area by the writer on behalf of the Mt. Lyell Mining and Railway Co., as part of a new approach to the solution of the problems of ore deposititon at Mt Lyell. The area then investigated included that part of the West Coast Range between Mt. Sedgwick and South Darwin, involving about 200 square miles of rugged terrain (Fig. 1). Aerial photographs of scale 1 inch = 1320 feet were used for mapping so that the survey was of a reconnaissance nature and hence by no means a complete study; similarly the petrographic work must be regarded as essentially preliminary. The specimen numbers quoted refer to the rock and slide catalogue of the Mt. Lyell Mining and Railway Co., Queenstown.

Discussion in this paper is confined to the Dundas Group which is of particular interest in that it is host to the Mt. Lyell copper deposits and contains a variety of rock-types which have puzzled geologists for many years. The Group was defined by Elliston (1954) as the sequence of sediments and volcanics exposed near Dundas township, underlying the Junee Group and overlying the Carbine Group (Precambrian). As a result of regional mapping programmes by private enterprise, Government departments, and the University of Tasmania, the extent of the Dundas Group outcrop on the West Coast has been determined approximately, correlations being made largely by lithology and continuity of outcrop but occasionally on palaeontological evidence. Those fossils collected to date show a range from the *Ptychagnostus gibbus* Zone to the *Glyptagnostus reticulatus* Zone, or approximately Upper Middle Cambrian to basal Upper Cambrian (Banks, 1956). No fossils have been found near Queenstown and correlation is made by continuity of outcrop from areas to the north, by lithology, and by relationships to overlying beds. The base of the Group is not exposed in this area.

The sediments of the Dundas Group are thought to have been deposited in a geosyncliinal basin which extended over at least western Tasmania and part of Victoria (represented there by the Heathcotian Series) and the abundance of volcanics has led to the use of the term eugeosyncline (Kay, 1947) for the basin of deposition.

A feature of the Dundas Group on the West Coast is the development of a considerable thickness of dominantly volcanic material along the West Coast Range. This was recognised by Carey (1950, 1953) and further emphasised by Campana *et al.* (1958) in their subdivision of the Group into a "bedded series" and a "volcanic assemblage". The latter is particularly well exposed in the Bulgobac-Pinnacles-Rosebery-Mt. Tyndall area and forms a sharply defined N-S zone of dominantly volcanic rock, while the Dundas Group to the west is essentially a sedimentary sequence.

Elliston described considerable thicknesses of agglomerate and tuff in the succession at Dundas but these beds are now recognised as non-pyroclastic and it is clear tht the type section belongs to the "bedded series".

South of Mt. Tyndall the volcanic assemblage of Campana *et. al.* is difficult to distinguish as its percentage of sedimentary rocks increases and lavas become ubiquitous. As a general rule all Dundas Group sections south of the latitude of Mt. Sedgwick contain roughly equal proportions of volcanics and sediments.

The volcanic zone between Bulgobac and Mt. Tyndall is interpreted (Carey, 1950) as marking a line of volcanoes in the Cambrian eugeosyncline and Campana *et al.* have related this zone of volcanic activity to the early phases of rift valley formation.

No fossils have been reported in the volcanic zone and its stratigraphic relationship to the bedded series is unknown.

## PREVIOUS STUDIES AND PRESENT VIEWS

Gregory's (1905) descriptions of the Dundas Group rocks in the Queenstown area, including chemical analyses and petrographic data, are still referred to. Of the earlier contributions from the Tasmanian Mines Department the most useful accounts of the Cambrian rocks are those by Twelvetrees (1900) and Hills (1914) on the Jukes-Darwin mining district and Hills (1927) on the Lyell field. Nye, Blake and Henderson (1934) completed a generalized survey of the area north of Mt. Jukes and their views on the origin of the Cambrian rocks were opposed to those expressed by Hills. Although later workers on the Mt. Lyell leases (e.g. Edwards, 1939; Conolly, 1947; Alexander, 1953) followed Nye *et al.*, recent work confirms Hills' conclusions that the Cambrian rocks are largely of volcanic origin.

Hills and Carey (1949) and Carey (1953) discussed problems of West Coast geology and Banks (1956) included local information in his summary of the Dundas Group in Tasmania. The regional geology has been dealt with at length by Bradley (1954, 56, 57) and summarized by Wade and Solomon (1958).

The earlier geological opinions on the nature of the Dundas Group in this area varied from intrusive complexes with sedimentary roof-pendants (e.g. Nye, Blake and Henderson; Edwards; Conolly), to volcanics with minor sediments (e.g. Hills 1914, 1927) while others have suggested combinations of these extremes (e.g. Gregory, 1905). In 1953, Carey obviously considered that many of the so-called pyroclastics were greywackes and he stressed the sedimentary nature of the Group as a whole; he also heralded and supported the work of Bradley, who introduced a new approach when he postulated that many of the igneous rocks were a result of metasomatism of greywacke sediments and basic lavas, the metamorphic processes being a Tabberabberan age and related to sulphide mineralization. He envisaged the extensively developed quartz and feldspar porphyries (the term porphyry is used in this text to describe a rock showing porphyritic texture) as originating by "porphyritization", involving growth of feldspar and quartz *in situ*, whereas all earlier workers had considered these rocks to be igneous. He was supported by Scott (1954) though she suggested the metasomatism only affected basic lavas and was of late Cambrian age. These views have been criticised by Banks (1956) and Wade and Solomon (1958) and it is now suggested that the Dundas Group in the Queenstown area comprises a suite of only slightly metamorphosed lava flows (varying from rhyolites to basalts), agglomerates, tuffs, conglomerates, sandstones and slates. This is very similar to the description given by Hills 45 years ago.

Bradley's views were accepted by other workers (e.g. Carey 1953, p. 1109) probably largely because severe alteration of the Dundas rocks was obvious near the Lyell deposits and it seemed reasonable to assume a more "regional" metasomatism involving porphyritization and granitization. However, Cambrian sequences in areas further afield, where there is no obvious metamorphism, contain identical porphyries and there is no reason to believe these are metasomatic. Examples include the Cambrian rocks in the D'Aguilar Range (south of Macquarie Harbour), on the High Rocky Point-Point Hibbs coastline, and in the Tullah-Mt. Farrell area. Those on the Southern Ocean coast are somewhat lenticular bodies interbedded with sediments( and pyroclastics ?) and varying from a few inches to several hundred feet thick. They are fine grained, porphyritic, locally vesicular and a few exhibit scoriaceous tops. The evidence is overwhelmingly in favour of these rocks being lava flows. The Tullah and D'Aguilar Range bodies are less well exposed but they appear to be concordant igneous porphyries.

Further and more direct evidence that the Queenstown porphyries are igneous is provided by the discovery in them of high-temperature quartz crystals (see p. 4). Several of these porphyry occurrences (e.g. the Lynch Creek area) are lenticular, concordant, vesicular and amygdaloidal, fine grained, associated with pyroclastics and similar to lavas of other areas, so that they are almost certainly volcanic. However, some of them (e.g. in the West Queen River and near Little Owen) have elliptical, almost circular outcrops and show discordant contacts; these are either intrusions, or volcanic necks, or steep-sided Peléan-type domes of viscous lava, burial of which by ash and sediment has produced pseudo-discordant relationships at their margins.

The majority of the porphyries are very probably lavas, judging by field relationships, similarities to other flows, and both macro- and microscopic textures, but there may be instances of intrusive bodies.

## VOLCANIC ROCKS

### Lavas

The principal lava-types observed in the Queenstown-Darwin area are as follows:

#### Spherulitic potash rhyolites

On Mt. Darwin, Intercolonial Spur, Whip Spur and Mt. Sedgwick (Fig. 1) are found distinctive massive outcrops of closely jointed, pink haematitic

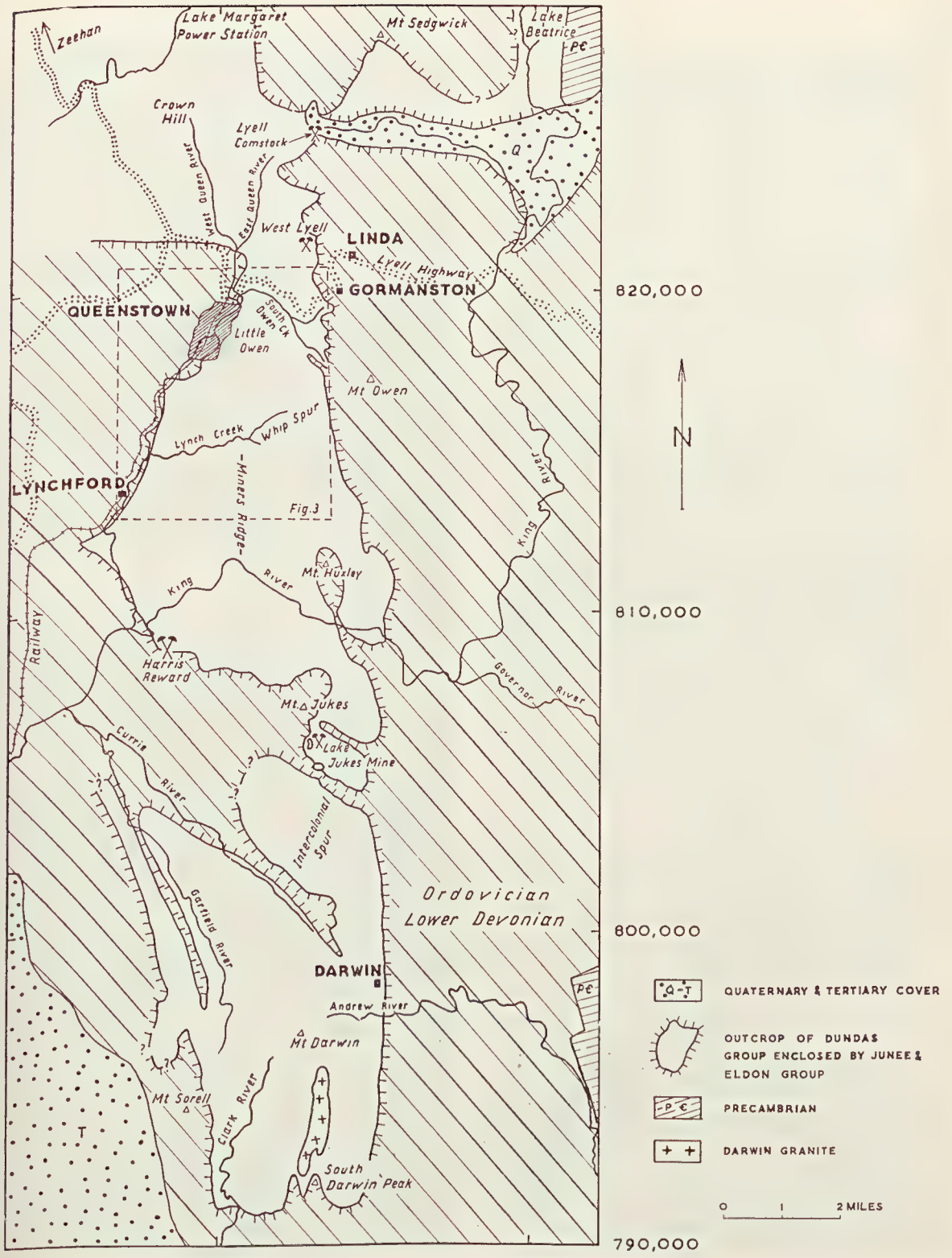



FIGURE 1.—The Queenstown Area.

feldspar porphyry (D 32, 33). The outcrops of these porphyries, in plan, vary from those which are almost circular (e.g. Whip Spur and Mt. Sedgwick) to those with one dimension much greater than the other (e.g. Intercolonial Spur). Possibly the former represent volcanic necks of Peléan cores while the latter are flows. The groundmass of these porphyries is aphanitic and the pinkish feldspar laths are up to 3 mm. long and very sparsely distributed. In places, and particularly south-east of Mt. Sedgwick, the rock is laced with haematite magnetite veins which are up to two feet wide, generally lenticular and of random orientation.

Microscopic study of typical porphyries on Mt. Darwin and Intercolonial Spur show the phenocrysts to be subhedral laths of plagioclase feldspar (albite ?) many of which show slightly corroded margins. Alteration of some crystals is slight, but in others it is so intense that the crystal is merely an outline in a microcrystalline "felt" of sericite, calcite, &c. The groundmass, which may form more than 90% of the rock, is composed mainly of rather crudely developed spherulites generally less than 0·5 mm. diameter. These usually possess a core of clear quartz and often a rim of quartz or dark brown haematitic (?) "dust" (Fig. 2). Notable features of the chemical composition of a typical sample of this rock are the high silica and potash percentages (73·4% $SiO_2$, 8·0% $K_2O$—see Table 1, No. 1). Sodium-cobaltinitrite stain tests (Chayes, 1952) gave negative reactions on the phenocrysts and strong indications of positive reactions throughout the groundmass. Though the fine grain of the base reduces the certainty of the latter observation, the stain results and the chemical analysis together suggest that much of the groundmass material is potash-feldspar.

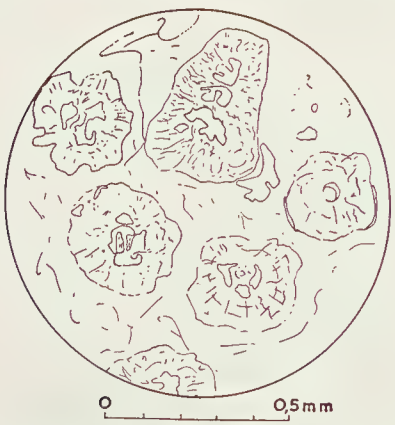



FIGURE 2.—Spherulitic forms in potash rhyolite, Mt. Darwin. Clear material in the spherulites is quartz.

Similar rock (Q 75) forms a bold outcrop at the head of Whip Spur (see Figs. 1 and 3). Albite (?) phenocrysts up to 2 × 1 mm. in size occur in a microcrystalline feldspathic ground mass in which spherulites abound; these are less than $\frac{1}{8}$ mm. diameter, consist of radiating fibres and have a thin dark circumference like many of those described from Mt. Darwin. Once again the base reacts positively to potash stain tests. A fine banding which shows on some weathered faces is interpreted as flow banding.

An interesting variant (D25) acts as host to the Lake Jukes copper orebody. It is a dense, mottled, pink and grey "felsite" similar to the porphyries just described but differing in locally showing micrographic texture between quartz and potash (?)-feldspar. Hills (1914) describes the rock as a granophyre. The texture may be primary but could also result from reconstitution of a spherulitic base during mineralization. Breccias and banded rocks associated with this and other potash rhyolites are described under the heading "Pyroclastics" on p.

The outcrops of the pink rhyolites are confined to a narrow zone roughly coincident with the axis of the West Coast Range between South Darwin and Mt. Sedgwick, and the only other occurrences known to the writer are at Red Hills, South Mt. Farrell and near Lake Rolleston, all within the West Coast Range. This localization suggests the existence of a narrow zone of distinctive volcanic centres in Cambrian times from which acid, potash-rich lavas were erupted. It is significant that a major part of the only granite of proved Cambrian age in the Queenstown area is of similar composition to these rhyolites and is intruded into them.

### Quartz keratophyres

Quartz-feldspar porphyries outcrop in the West Queen River, at Harris' Reward pack bridge (over the King River), in the Garfield River, west of Mt. Sedgwick, north of Darwin and at many other places within the area under discussion. Outside the area, similar rocks occur near South Mt. Farrell, Lake Dora and over a wide area north of Boko Siding on the Emu Bay Railway.

The boundaries and precise shapes of these quartz porphyry outcrops are always difficult to define though generally the bodies conform to the local structural trend. The porphyry exposed in the West Queen River has an elliptical outcrop roughly concordant with the regional strike but its southern margin appears to cut across steeply dipping sandstone beds. This porphyry (Q31) is pink or grey in colour with phenocrysts of both clear quartz and feldspar set in an aphanitic groundmass. Thin section study reveals that the quartz phenocrysts show some well-defined crystal faces but most are corroded and embayed and frequently contain inclusions of the ground mass. A few of the crystals show fuzzy, poorly defined boundaries.

Bradley (1957) has discussed similar observations on this and other quartz porphyries and he considers they indicate that the phenocrysts have grown *in situ* by a metasomatic process involving solid diffusion. Actually all the features described are typical of present-day and ancient acid eruptives, the corrosion, embayments, &c., being attributed to reaction between developing quartz crystals and the residual liquids. Proof of their igneous origin has been provided by Dr. E. Williams who has shown me etched basal sections of quartz crystals from West Coast porphyries that

clearly display the cracking and heterogeneous twinning typical of the high temperature form. The feldspars of the West Queen River porphyry occur as hypidiomorphic crystals in approximately equal quantity to the quartz, the phenocrysts of the two minerals forming 60% of the typical rock. Few feldspar crystals show embayments or inclusions but many are markedly zoned, a feature which is often highlighted by alteration of the core to chlorite and the rim to sericite (?). Some of the crystals are clear, unaltered albite but the majority are clouded by alteration products and appear to have a composition of about $Ab_{90}$. Ferromagnesian minerals are very scarce though chlorite and haematite confined in idimorphic lath outlines suggest that some ferromagnesian mineral was once present in the rock.

The groundmass is a microcrystalline aggregate of feldspar, chlorite, and haematite of which the texture is obscured by alteration products.

A feature of these quartz porphyries and also the feldspar porphyries (keratophyres) is the presence in irregular patches of chlorite-albite ($Ab_{98}$) aggregates some of which occur isolated in the groundmass but many of which are clearly replacing altered feldspar laths. Many are only visible under the microscope but others are seen in outcrop as vughs partially filled with albite, chlorite and epidote. The albite is characteristically confined to the rim while the ferromagnesian minerals fill, or partially fill, the core. A specimen in the Mt. Lyell Mining and Railway Company's collection, presented by Professor J. W. Gregory in 1903, is a feldspar porphyry from the East Queen River with a vugh several centimetres across lined with albite, epidote and quartz. There is every gradation between typical zoned amygdales and irregular " clots " derived from feldspar alteration and they are all regarded as expressions of late-stage gas action (i.e. deuteric phenomena). The albite of this phase is usually pink or brown in colour and appears fresh and unaltered under the microscope.

A chemical analysis of a large specimen of typical West Queen River porphyry is given in Table 1, No. 3; in conjunction with the petrographic data it suggests the rock should be identified as a quartz keratophyre. The latter term is used to denote a rock with the chemical composition of a sodic rhyolite but with abundant albite or oligoclase and a very small percentage of primary ferromagnesian mineral, which is altered to chlorite. It is distinguished from keratophyre by abundant free quartz and consequent higher silica percentage. Gregory (1905, p. 57) described a quartz-feldspar porphyry from the Lyell Comstock tram line as a diabase porphyrite. However, his petrographic description and the chemical analysis he provided (see Table 1, No. 4) suggest he had examined a rhyolitic flow.

A striking quartz keratophyre (Q22) outcrops in a small quarry west of the Zeehan road three miles from Queenstown. It is a pink-brown porphyry containing prominent amygdales lined with albite and filled with chlorite and occasional specks of galena. The majority of the phenocrysts are of altered plagioclase feldspar in laths up to 4 mm. long, the remainder being of corroded quartz crystals and irregular, rounded masses of chlorite with dark rims which may represent altered feldspar crystals. The chlorite shows the dark blue or rich brown interference colours typical of pennine. The groundmass is a microcrystalline aggregate of quartz and feldspar, speckled with pyrite grains and containing rare apatite crystals.

A slightly different variety of quartz porphyry outcrops on the tram line between the upper and lower power houses at Lake Margaret. It varies in colour from grey-blue to yellowish grey and contains phenocrysts of quartz, feldspar, and chlorite up to 4-5 mm. diameter. The idiomorphism of the quartz crystals and zoning in the feldspars are visible in hand specimen.

### Sodi-potassic rhyolite

Half a mile south of the upper zig-zag on the Lyell-Comstock tram line and on the west side of the East Queen River, there are bold outcrops of grey feldspar porphyry (Q23), parts of which show banding. Colours of individual bands vary from pale to medium grey and hence they are not particularly distinct; they vary from a few millimetres to a few centimetres in thickness and are impersistent.

Many of the phenocrysts, which average 2 mm. across show vestiges of multiple twinning but they are so clouded by alteration products that identification is difficult; extinction angle measurements indicate a composition of about $Ab_{88}$. They are enclosed by a quartzose (?) microcrystalline ground mass.

This rock was described by Bradley (1954, p. 223) as a soda trachyte but chemical analysis (Table 1, No. 5) of a specimen reveals a high silica content (72·9%) and roughly equal amounts of soda and potash, so that the term sodi-potassic rhyolite seems more appropriate until more definite petrographic data are available.

### Keratophyres

Sodic feldspar porphyries of various types occur throughout the Dundas Group and are the most common of the lava-types in the Queenstown area. They are particularly well exposed at several places along the Lyell-Comstock tram line, on the Zeehan road, east of Mt. Sorell, and north and east of Mt. Jukes. Similar rocks make up the bulk of the " volcanic assemblage " (of Campana *et al.*, 1958) which outcrops between Rosebery and the Sterling River Valley, and between Farrell Siding and Tullah.

Deeply weathered lavas of this type occur at the northern end of the Queen River gorge where they are interbedded with beds of slate several feet thick; at their base the flows have picked up and incorporated fragments of the underlying sediments. Along the Lyell-Comstock tram line the lavas are interbedded with conglomerates, pyroclastics and thin beds of banded slate.

These porphyries (Q15, 26, 27, 29, &c.) are characterised by subhedral feldspar laths up to 1 cm. long, very fine or microcrystalline matrices, and " clots " of albite-chlorite crystals which are

taken as evidence of deuteric action. The feldspar phenocrysts are generally intensely altered, either to albite-chlorite, or to a dense brown "felt", but examination of fresher remnants indicates a composition near $Ab_{90}$. Small amounts of calcite have been observed as an alteration product of feldspar. Augite and hornblende laths, generally considerably chloritized, and embayed quartz crystals rich in inclusions are rare constituents. The groundmass in some thin sections is speckled with haematite and apatite crystals are observed occasionally.

Most of the feldspar porphyries can be classed as keratophyres, assuming that term to include trachytic rocks characterised by a relatively high soda content, the presence of abundant albite or oligoclase and intense alteration of what little ferromagnesian mineral may have been present in the rock. In this area there are all gradations to sodic rhyolites on the one hand and to albite andesites on the other, with the result that there are considerable ranges in the chemical composition of the keratophyres. The analysis of the feldspar porphyry given in Table 1, No. 6 is typical of a rather more basic variety and on chemical composition alone would be described as a trachyandesite. It is transitional between the true keratophyre and the hornblende andesite in that it contains laths of hornblende and augite up to 1 × ¼ mm. in size and partly altered to chlorite.

### Augite Trachyte (?)

East of the Queenstown-Lynchford road (see Fig. 3) the grass-covered hills display tors of feldspar-pyroxene rocks and on some of the tor faces can be seen haphazardly distributed fragments of sedimentary rocks and basic lavas.

This rock has a rudely equigranular, more or less reticulated texture, with a grain size of about 1 mm. and sparse interstitial material. The feldspar content varies from 30% to 90%, the remainder of the rock being composed of augite (diopside ?), quartz and the microcrystalline base. The feldspars occur as stumpy subhedral laths, only slightly altered and with a composition of $Ab_{95}$. The augite crystals are anhedral, fractured, and partially altered to chlorite and locally form 30% of the rock. Clear albite veinlets traverse the rock and albite-chlorite aggregates (amygdales ?) are common.

From petrographic data, Twelvetrees (1902, p. 282) considered the rock to be extrusive and described it as a syenite porphyry. Bradley (1954) included it in his "Lynch Conglomerate" formation and considered it to be a sediment derived from weathering of underlying basalts. He inferred an unconformity at its base.

The outcrop (Fig 3) is nearly two miles long and relatively narrow and it is clearly concordant with contiguous beds. From the evidence outlined it is impossible to differentiate between suggestions that the rock is a crystal tuff, a lava, or a sill, but it is most unlikely to be a sediment. Its texture is rather similar to that seen in tuffs near Lyell Comstock described on p. 43.

South-east of Little Owen there outcrops a rock of similar composition but with a more pronounced porphyritic texture; on its northern margin it is interbedded with sandstones and tuffs but the major part of the outcrop shows discordant relationships to the neighbouring rocks. This occurrence therefore has more the features of an intrusion and may represent a section through a volcanic cone.

The only other example of this rock-type with which I am acquainted occurs as boulders on the side of the Zeehan-Comstock road nine miles from Zeehan. The boulders are in Pleistocene moraine and are derived from the plateau south of Mt. Dundas. One of them contains randomly oriented fragments of finely banded siltstone that appear to have been hornfelsed at their margins by baking. The inference is that the host rock was hot and probably fluid.

In summary then, the available evidence suggests that this rock-type may occur as an intrusive, a pyroclastic or as a lava flow. In all probability all these modes of occurrences exist and they are clearly interconnected. Uncertainty as to its exact nature makes it difficult to define the rock but tentatively it is named after the lava-type of similar composition; several occurrences of other lava-types may similarly be actually intrusive or in part pyroclastic.

The chemical composition of a sample gathered 500 feet east of Lynch Creek bridge is given in Table 1, No. 7. Although clearly related to the keratophyres and andesites of the area it is a distinctive rock type and warrants a particular term. Despite the abundance of albite and high soda content, the presence of augite invalidates the term keratophyre and augite trachyte is preferred.

### Andesites

Many of the hill-tops in the Comstock-Crown Hill area are capped by tors of hornblende and augite porphyry. These rocks are typically grey or pinkish-brown in colour and composed of phenocrysts of feldspar and ferromagnesian minerals (up to 3 × 1½ cm.) set in an aphanitic ground mass. Similar rocks occur as boulders in the Lake Margaret moraine and outcrop west of Mt. Tyndall.

The texture of these porphyries (Q1, *7a*, *7b*, 8, 9, &c.) varies from seriate to porphyritic and the dominant mineral is feldspar occurring as phenocrysts and in the very fine grained groundmass. It is generally clouded and partly chloritised but remnants of multiple twinning are discernible and extinction angle measurements indicate a composition of $Ab_{70}$. Zoning is common, many crystals showing a clear albite fringe enclosing a core of altered $Ab_{70}$ feldspar.

Hornblende occurs as pale green crystals, usually deeply embayed and containing "inclusions" of the ground mass; in some cases the crystal is more of a skeletal framework. Some have a dark rim and a core of chlorite, others are represented by chlorite-haematite aggregates.

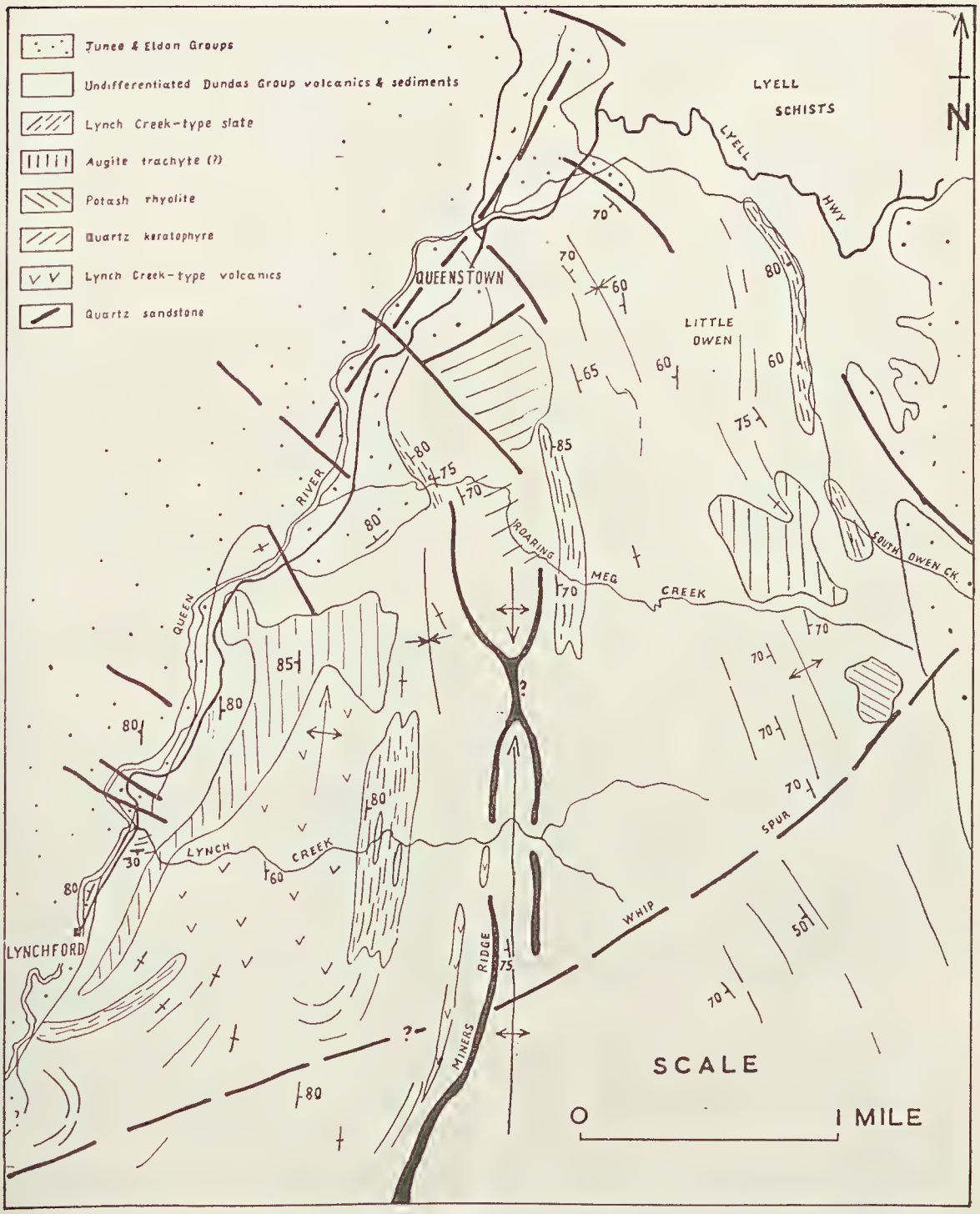



FIGURE 3.—Geological Map of the Lynch Creek Area.

There is every variation from hornblende porphyry without augite to augite porphyry with little hornblende; the total percentage of ferromagnesian minerals is constant and thus where there is much of one mineral there is little of the other. The augite (diopside ?) occurs as cracked and poorly formed crystals, generally partly chloritized.

Quartz occurs sparsely in the form of shards or in clusters of fragments showing unit extinction (presumably representing a fragmented crystal). The remainder of these rocks is usually made up of a dark, partly feldspathic matrix, fragments of feldspar-pyroxene lava, and ragged crystals of calcite. Albitization of these rocks varies from slight to intense, a more severe case being illustrated in Plate 1, Fig. 1. Here the albite replacement has proceeded to such a degree that a brecciated appearance has resulted. The isolated blocks of hornblende porphyry average 3 dm. across and are separated by pale albite rock containing some hornblende crystals. Some of the thin sections show irregular replacement zones of albite and one contained in addition a number of dilatational veinlets. A specimen taken on the west slope of Crown Hill contained in the groundmass tiny (0·1 mm.) spherulites of radiating albite (?) fibres; the spherulites gave the typical "cross-figure" when rotated between crossed nicols. Near the summit of Crown Hill the porphyries show banding, "pebble" outlines and inclusions of sediments or tuffs.

Chemical analysis of typical slightly albitized hornblende porphyry from Crown Hill (Table 1, No. 8), taken in conjunction with petrographic data suggests a suitable name for the rock is a hornblende (or augite) andesite.

Scott (1954) regards these andesites as originating by metasomatism of basic lavas, the hornblende crystals growing out of chlorite which has developed through breakdown of pyroxene. I was unable to establish definitely the relationships between hornblende, augite and chlorite but gained the impression that chlorite formed from both augite and hornblende. Probably the chloritization and albitization are deuteric or secondary phenomena and are obscuring the magmatic hornblende-augite relationships. Scott (1954, p. 141) discusses at length the parallelism of hornblende laths in a boulder of andesite observed by Banks in the Margaret moraine. The orientation of the laths is at an angle to the cleavage and she is unable to explain the feature by her metasomatic theory for the development of hornblende. In all probability it is a primary flow phenomenon.

### Basalts

Basalts outcrop along Lynch Creek, between 1000 and 4500 feet east of the Lynch Creek bridge (see Fig. 3). Individual flows are limited in extent, in both horizontal and vertical direction, and they are associated with tuffs, siltstones and volcanic breccias. Red and brown clays are exposed along Lynch Creek in the walls of open cuts made during the pursuit of quartz-gold veins. These clays are probably tuffs and perhaps lavas that have been altered as a result of the mineralization, and since deeply weathered.

The lavas (Q82, 83, 88) are grey-green in colour and porphyritic, with phenocrysts of dark green pyroxenes up to 2 cm. long and smaller pale grey feldspar laths, set in an aphanitic ground mass. The pyroxene occurs in euhedral crystals, is only slightly chloritised and has been identified by Scott (1954) as diopside. Although Scott describes the feldspar laths as albite I found they were so altered that identification was difficult and that what few measurements could be made indicated a composition of about $Ab_{80}$. The relatively low soda percentage in these rocks (Table 1) fails to support Scott's determination.

Some specimens gathered from the volcanic sequence contain hornblende laths and are not unlike the hornblende andesites of the Crown Hill area.

The Lynch Creek lavas are associated with lenses of breccia; this is usually very coarse grained and consists of fragments of basalt embedded in a basaltic matrix which usually shows evidence of having "attacked" the fragments. These lava fragments differ from the matrix and also the majority of the flows in being markedly vesicular and amygdaloidal. The amygdales are spherical, up to 5 mm. in diameter, and are made up in the following ways:—

(*a*) Lined with albite enclosing a zone of haematite and a core of chlorite.
(*b*) Lined with calcite enclosing a chlorite core.
(*c*) Filled completely by calcite.
(*d*) Lined with chlorite enclosing a calcite core.

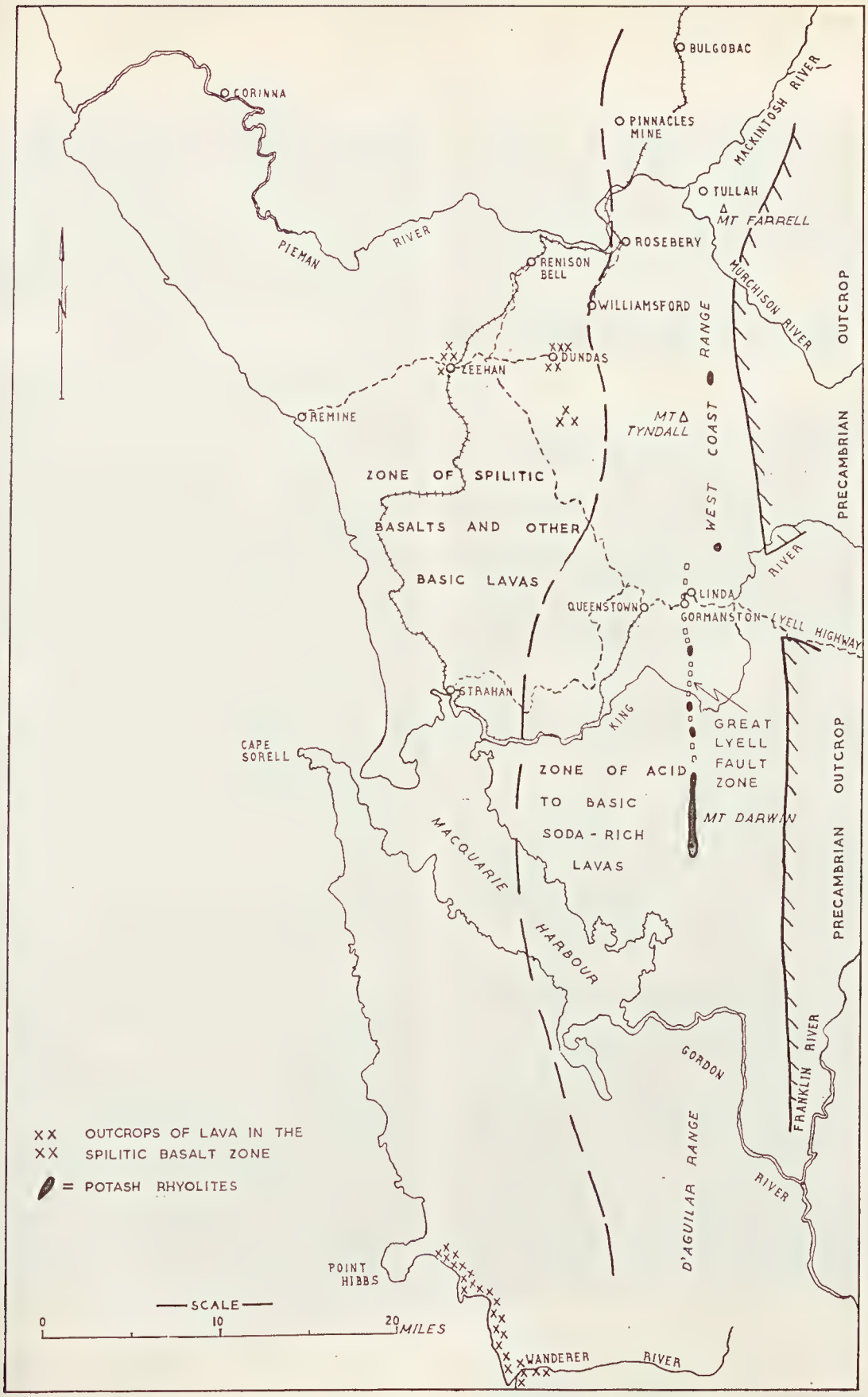
The breccias are thought to have originated by the process of "autobrecciation" whereby the chilled gas-laden crust on a mobile lava becomes broken up by, and incorporated into, the still molten rock beneath.

A variation (Q96) of the normal porphyritic texture is seen in a flow outcropping on the west flank of Miners Ridge; it is about 50 metres thick and extends for several hundred metres. The lava is composed of diopside and feldspar but has a roughly equigranular texture with augite granules set in a lattice-work of fine feldspar laths. A chemical analysis is given in Table 1, No. 12, along with others of the Lynch Creek basalts (Nos. 10 and 11).

Another suite of basalts with which I have a brief acquaintance occur outside the area now under discussion but are of some interest as regards distribution of lava types. They outcrop on the Southern Ocean coast between Point Hibbs and High Rocky Point and consist mainly of spilitic basalts and associated tuffs and breccias, very well exposed in steep cliffs. The flows vary from a few inches to over 100 feet thick, are fine grained apart from local coarser zones, and are dark or medium grey in colour. While some flows are homogeneous others are severely brecciated, resulting in a "conglomerate" of lava fragments in a lava base, similar to those described from Lynch Creek.

The commonest type is a grey porphyry with feldspar phenocrysts and dark euhedral augites set in an aphanitic, dark ground mass. The feld-

FIGURE 4.—Distribution of lava-types in the Dundas Group.


BULGOBAC
CORINNA
PINNACLES MINE
MACKINTOSH RIVER
TULLAH
MT FARRELL
PIEMAN RIVER
ROSEBERY
RENISON BELL
WILLIAMSFORD
MURCHISON RIVER
OUTCROP
PRECAMBRIAN
ZEEHAN
DUNDAS
WEST COAST RANGE
REMINE
MT TYNDALL
ZONE OF SPILITIC BASALTS AND OTHER BASIC LAVAS
QUEENSTOWN
LINDA
GORMANSTON
LYELL HIGHWAY
RIVER
STRAHAN
KING
GREAT LYELL FAULT ZONE
CAPE SORELL
ZONE OF ACID TO BASIC SODA-RICH LAVAS
MT DARWIN
MACQUARIE HARBOUR
GORDON
FRANKLIN RIVER
D'AGUILAR RANGE
RIVER
POINT HIBBS
WANDERER RIVER
XX OUTCROPS OF LAVA IN THE
XX SPILITIC BASALT ZONE
= POTASH RHYOLITES
SCALE
0
10
20 MILES

spars are slightly chloritized, euhedral, albite crystals generally less than 1-2 mm. long; similar feldspar is discernible in the groundmass either as scattered tiny laths or forming a microcrystalline lattice of laths with interstitial pyroxene granules.

Amygdales are seen occasionally in thin sections and are usually circular or lenticular in shape, consisting of clear albite enclosing a central zone of chlorite.

These basalts have strong spilitic affinities and are similar to spilites described by Scott from King Island, Penguin, and Zeehan. Some of these have " pillow " structures and are in all probability of submarine origin.

### Summary of Lava Descriptions

The Queenstown area exposes a continuously variable series of volcanic rocks ranging from basalts through andesites to rhyolites. The alkali content is equally variable, potash-rich rhyolites being associated with soda-rich keratophyres and relatively alkali-poor basalts. Apart from the potash-rhyolites the dominant primary feldspar type varies from $Ab_{80}$ to $Ab_{98}$ in composition and the rocks have undergone varying degrees of albitization. Though these rocks were predominantly extrusive the discordant contacts mentioned in a few cases suggest some of the occurrences are actually intrusive, in the form of small sills, plugs, or vent-fillings.

Association of the lavas with slates and sandstones suggests the environment was at least temporarily aqueous and it probably ranged in place and time from terrestrial to marine.

### Distribution of Lava Types

A notable feature of lava distribution in the Queenstown-Darwin area is the concentration of the potash rhyolites along a narrow N-S belt which coincides with the axis of the West Coast Range and locally with the Great Lyell Fault Zone. (see Solomon, 1959, p. 36). The Darwin Granite, of very similar composition, also occurs along this fault zone between Mt. Darwin and South Darwin (Fig. 4).

Away from this belt the lavas vary from basalts to rhyolites but are characterized by dominance of soda over potash.

Viewing the West Coast as a whole, a tripartite division of lava types can be recognised:—firstly the narrow, relatively insignificant potash rhyolites occurring within a wider zone of variable but soda-rich volcanics, which in turn is flanked on the west by a still wider area in which the majority (say 80%) of the lavas are basic and sodic (see Fig. 4).

The central acid to basic zone in the Queenstown area has a poorly defined western boundary partly due to lack of exposure but to the north, and particularly in the Rosebery district, the western edge is sharp and coincides with the bedded series—volcanic assemblage interface. The volcanics here and to the north are made up of similar lavas to those seen near Queenstown. West of Rosebery and Williamsford, the lavas of the basic zone are subordinate to sediments and are largely basic in character (e.g. the Curtin Davis Volcanics and the Montana Melaphyre, Elliston, 1954, and Scott, 1954) and only rare acid lavas have been recorded (e.g. at Montana, Twelvetrees and Ward, 1910, p. 19). In the Point Hibbs-High Rocky Point area the percentage of lavas in most of the Cambrian sequence is greater than that of the sediments but the dominance of basic types is maintained.

### Cause of the Distribution

Again insufficient is known of the Cambrian palaeogeography and tectonic environment to be certain of the cause of the lava distribution described.

An important feature, however, is that the lava zones are roughly parallel to the western margin of the Precambrian outcrop, a relationship which appears to be continued north-east of Bulgobac (Fig.. 4). The present Precambrian limit roughly coincides with the Cambrian margin of the Tyennan Block, a relatively stable area which Carey (1953) considers to have had a considerable influence on Palaeozoic sedimentation and tectonics and which was very likely exposed during the Cambrian. The narrow zone of volcanoes that are assumed to have built up the " volcanic assemblage ", and another related to the potash rhyolite distribution, are both parallel to the Tyennan Block margin and may be imagined as lines of off-shore volcanoes in the Cambrian depositional area. These volcanic lines roughly coincide with major Devonian structures such as the Great Lyell Fault Zone and probably are expressions of Cambrian movement along these features, which also appear to be influenced by the Tyennan Block.

### Albite in the Lavas

Scott (1950) has described albite in ophitic texture with diopside in Cambrian basalts from King Island and this is strong evidence that albite occurs as a primary mineral. The presence of fresh albite in tuffs north of Queenstown (see page 43) suggests the mineral formed at an early stage in crystallization and the fresh albite crystals in the augite trachytes, and also in some of the quartz keratophyres, has the appearance of a primary mineral.

The existence of rims off clear albite on more calcic feldspar indicates a phase of albite formation related to soda-enrichment of the residual material of the cooling flow. Albitization of an even later phase is seen in the veinlets and the chlorite-albite aggregates; these are observed mainly in lava flows but the presence of similar features in pyroclastic rocks indicates the mobile material circulated beyond the limits of the flows. The continuity between the chlorite-albite " clots " and amygdales suggests this late albitisation is related to the release of volatiles from the lava.

It is accompanied by chloritization of both primary feldspars and ferromagnesian silicates.

Scott (1954) considers the albitization to be part of a widespread late Cambrian metasomatism involving not only albite introduction but also chloritization, silicification and carbonation. Actually chlorite and albite are the only replacement minerals of Cambrian age in the Queenstown area and their mode of occurrence suggests they are of igneous origin. With regard to the source of the soda in the porphyries she concludes (p. 144) that it is derived from connate waters trapped in the lower levels of the eugeosynclinal sediments. I would prefer to leave the problem with Turner and Verhoogen (1951, p. 210), who state when discussing olivine basalt magma: "Differentiation of the magma, assimilative reaction with rocks situated in the basal levels of the geosyncline, concentration of magmatic water rich in soda, and chemical activity induced by entrapped sea water and rising connate waters squeezed up from deeply buried sediments, are all factors of possible significance in evolution of spilites and keratophyre".

The albite described above is a pinkish brown in colour and easily recognizable. Albite with a reddish tinge is often seen in quartz veins in the schists at Mt. Lyell and in the vicinity of other sulphide deposits; the veins are clearly post-schistosity and related to Devonian mineralization and this albite is perhaps derived by solution from soda-rich Dundas Group lavas and tuffs.

## PYROCLASTIC ROCKS

**Agglomerates** (fragments over 32 mm. diameter.)

Conglomeratic and breccia lenses are a feature of the Dundas Group in the Queenstown area. When the constituents are entirely of igneous origin, then the rock is probably the result of autobrecciation or may be a true agglomerate, particularly if associated with lavas. Many of the lenses show no stratification or sorting and could be products of the nuée ardente type of eruption. For instance, coarse breccias occur in the potash rhyolite assemblage on Mt. Darwin and also in the granophyric host to the bornite veins at Lake Jukes; generally the fragments vary from a few cm. to a few decimetres across, are angular to subangular, and of similar composition to the matrix. There is little or no stratification and the fragments are randomly orientated.

Apart from these breccias, which are fairly certainly of volcanic origin, there are many which contain varying percentages of sedimentary material such as siltstone and sandstone fragments. These could be volcanic, or pyroclastic rocks deposited in water or sedimentary rocks and proof of volcanic origin must depend on the recognition of volcanic glass; this, of course, is completely devitrified and in most cases it is impossible to decide whether the deposit is pyroclastic or whether it is reworked volcanic material. In the environment envisaged by the writer both types might be expected for the frequency of volcanic material suggests the Queenstown district in Cambrian times was one of considerable volcanic activity with eruption taking place from numerous centres of ephemeral nature. The constantly changing conditions would result in re-working of both land- and water-deposited pyroclastic and igneous material and would produce a complex, rapidly varying suite of sedimentary and volcanic rocks.

A typical conglomeratic rock (Q78) that is probably of mixed origin outcrops near the head of Whip spur some hundred metres west of the pink rhyolite. It occurs as lenses associated with finely banded mudstones and lavas and consists of coarse fragments of feldspar porphyry and sandstone and smaller quartz pebbles in a confused matrix of albite crystals, chlorite, and microcrystalline quartz (?) and feldspar (?). There is little stratification and the framework is disrupted. Veinlets and replacement zones of clear albite are common.

**Tuffs**

Again it is difficult to differentiate between sediments and volcanic deposits but there are a number of rock types that can be described as tuffs with reasonable certainty. For instance, at 8263/3584, on the Lake Margaret tram line west of Crown Hill (Fig. 1) is a distinctly banded rock (Q11) with an average grain size ½ mm. and a texture typical of orthoquartzites (equidimensional grains with an interstitial cement forming say 8-10% of the rock). It is composed of subangular grains of albite, quartz and hornblende (in order of abundance) and microcrystalline interstitial matter. The presence of banding, the texture and the anomalous composition (a high percentage of quartz compared with the local lavas) suggest the rock may be a tuff.

Similar remarks apply to a rock (Q17) forming tors above the northern zig-zag on the Lyell-Comstock tram line. It is mottled or rudely banded in pinks and dark greens, the bands being several inches thick, and it is interbedded with sandstones and paraconglomerates (i.e. conglomerates with disrupted framework and high matrix-pebble ratios). The rock has a granular texture, an average grain size about 1 mm. and is composed of quartz and fresh albite with sparse, fine grained, interstitial material which is locally chloritic (giving the dark green colour).

## SEDIMENTARY ROCKS

The relative proportions of sedimentary and volcanic rocks in the Cambrian sequence near Queenstown vary considerably and can only be determined approximately due to difficulties in identification. General field observations indicate that the proportion of sediments varies from a little above, to a little below, 50% in any square mile.

**Conglomerates**

The problems of identifying sedimentary conglomerates have already been discussed and rocks which are probably volcanic have been described. Those with more obvious sedimentary affinities are typified by the following examples:—at 8218/3588 there are outcrops of a deeply weathered, grey, feldspathic breccia-conglomerate containing fragments, sometimes "shard"-like, of slates and sandstone. The framework is disrupted and the distribution of fragments is chaotic, indicating rapid sedimentation.

Lenses of conglomerate occur in fine, grey sandstone in the Queen River gorge (south of Lynchford); an interesting type consists of small (up to 5 × 15 mm.) ovate pebbles of grey chert or very fine quartzite lying with long axes on the bedding planes, the plentiful interstitial material ranging from pebble size to microscopic and comprising "chert", quartz and rounded fragments of keratophyre. The source of the siliceous pebbles could be Cambrian chert beds, but none are known in this area and it is more likely that they are derived from Precambrian material.

A paraconglomerate containing sandstone lenses outcrops half a mile north-west of the Lyell Comstock open cut and immediately north of the mottled tuff described on p. 43. It is composed of fragments of volcanic and sedimentary material of Cambrian origin but in addition contains rounded pebbles of vein quartz identical with those which form the bulk of the Owen Conglomerate. It is thus very similar to typical Jukes Conglomerate but is almost certainly a member of the Cambrian sequence. Similar rocks occur throughout the Dundas Group (e.g. Elliston's Razorback Formation at Dundas) and grade, with increasing quartz pebble content, to siliceous breccias and conglomerates almost identical with beds in the Owen Formation. Thus there is good evidence that a Precambrian quartz-rich source was intermittently feeding material in limited amounts into the Cambrian eugeosyncline. Density currents sweeping off the Precambrian shoreline (to the east?) and also off the unstable volcanic belt probably carried much of the material into the "bedded series" depositional area.

The similarity of many of these Cambrian paraconglomerates to the Jukes Conglomerate renders impossible the positive identification of the latter formation by lithology alone.

### Sandstones

Several greywacke sandstones outcrop in the Queenstown-Darwin area. They are variable in character, lenticular, "dirty" or "muddy", and again it is often difficult to differentiate between greywacke sandstone and tuffaceous sandstone. Thin beds outcrop north-east of Lynchford and a considerable thickness may be seen east of Little Owen (see p. 46).

The one exception to the greywacke-type sandstones is the clean, quartz sandstone (Q101) which outcrops along the crest of Miners Ridge east of Lynchford (Fig. 3). It is about 100 feet thick and can be traced for four miles; its grain size varies between ¼ mm. and 1/30 mm. and it consists entirely of subangular quartz grains apart from a small number of biotite flakes aligned parallel to the poorly developed cleavage. It is interbedded with slates and is of some importance in that its prominent outcrop makes it a useful marker horizon for determining structure.

### Mudstones and Slates

These beds consist of finely, irregularly alternating bands of coarse siltstone (or very fine sandstone) and claystone. The claystone bands are thickest and consist of argillaceous material studded with quartz grains of silt grade; the narrower siltstone bands are usually composed of angular and subangular quartz grains of silt grade. Locally a tendency to grading is seen and the bands look similar to varves. Very fine ripple markings and erosion of tops of layers are seen occasionally and good examples of slump structures on a small scale outcrop on Whip Spur (see also Bradley 1954, p. 223). An indication of the frequency of banding is given by measurements made on the polished face of a specimen in the Mt. Lyell Mining and Railway Company's geological museum; in a nine-inch section the frequency of bands varies from one band per inch to 35 bands per inch.

Bradley (1954) has described these beds as exposed in Lynch Creek and termed them the "Miners Slates". As a cleavage is developed in the rock the lithology is correctly named but the Miners Ridge, from which the term is derived, is actually due to the quartz sandstone already described. "Miners Slates" (see p. 46) outcrop over a wide area as isolated lenses which merge along strike to other Dundas Group rocks, these facies variations render suspect the use of the slates as marker beds and suggest that mud and silt developed in local, ephemeral basins through a considerable range of the Cambrian.

The principal accessible exposures are along Lynch Creek, in the Queen River gorge, and along South Owen Creek (east of Queenstown). The most continuous outcrop mapped so far is in South Owen Creek, where the slates have been traced for 1½ miles with a fairly constant thickness of 300 feet. They outcrop either in low rises or in stream beds depending on the relative resistance of the propinquent beds. Rather similar finely banded rocks outcrop over a wide area around the junction of the Garfield and Currie rivers (Fig. 1) but the stratigraphic position of these beds is not known (they may, in fact, be of Silurian age).

The slates of the Tullah area and of the Rosebery and Hercules mines are very similar in lithology to the Lynch Creek slates.

## STRUCTURE

Determination of structures in the Cambrian rocks is hampered by rapid lithological changes along strike and the consequent lack of "marker horizons", and also by the fact that few of the rock types display identifiable bedding planes.

However, the presence of relatively persistent units east of Lynchford has allowed at least a partial portrayal of the fold styles in that area. The folds are only slightly asymmetrical, have steeply dipping limbs, and wave lengths averaging about 4000 feet. The axial trend in this district is 180° and there are fairly frequent changes in the direction of plunge. East of Queenstown the folds have NW trending axes and they plunge NW (Fig. 3). The north point shown on Fig. 3 is magnetic with declination 10° E.

Folds on these trends affect the Junee and Eldon Groups and clearly belongs to a Devonian orogeny, yet there is good evidence that faulting, uplift and

erosion affected the Cambrian sequence prior to deposition of the Junee Group. The presence of pebbles of Darwin Granite and Dundas lavas in the Jukes Conglomerate and the history of the development of the Jukes Trough (or Owen Rift valley), in which the Owen Conglomerate was later deposited, clearly indicate major faulting on N-S trends followed by erosion of elevated areas (see Bradley, 1954, 56; Wade and Solomon, 1958; Campana *et al.*, 1958). A good example is the uplift and erosion of the Darwin Granite late in the Cambrian and prior to deposition of the Owen Conglomerate. This tectonic phase has been termed the Jukesian Movement by Carey and Banks (1954). Clearly defined and indisputable unconformity between the Junee and Dundas Groups has not been proved on the West Coast, to the writer's knowledge, but it has been inferred at several places. A very strong indication of unconformable relationships in the Queenstown district is found near Lynchford, on grounds of discordance of lithology trends and observed dips (Fig. 3) and also at Mt. Sedgwick, where the base of the Jukes Conglomerate appears to cut through part of the Cambrian sequence. Yet at Mt. Misery (three miles east of Zeehan) the Gordon Limestone-Owen Conglomerate-Dundas Group succession is apparently conformable and Carey and Banks (1954) describe other areas showing a similar relationship.

As Bradley (1954, p. 205) has already pointed out the unconformity at Mt. Jukes described by Hills (1914) is actually a contact between gently dipping Junee Group conglomerates and Dundas lavas with a steeply dipping cleavage but in which no stratification is visible. A similar relationship is seen at the north end of Mt. Huxley where the basal beds of the Jukes Conglomerate and the underlying rocks of the Dundas Group are so sheared and altered that it is impossible to investigate the Dundas-Junee interface.

A complicating factor in determining Cambrian-Ordovician relationships is the likelihood of the interface acting as a décollement surface during Devonian folding, thus possibly producing "pseudo-unconformities". The chances of such a process taking place are increased in the areas where there are thick wedges of Owen Conglomerate that locally deflect and modify the Devonian stresses. Banks (1956, p. 204), by "unfolding" the unconformities he has observed and studying the residual pre-Junee dips, has concluded that the intensity of Jukesian folding varied from place to place. The force of his argument is reduced if it is accepted that décollement development is a real possibility.

In summary, there is evidence that faulting and unheaval preceded Junee Group deposition but the extent and precise nature of the movements is unknown. The variation in relationship between the Junee and Dundas Groups tends to support Banks' view of localised zones of tectonic activity but study of this tectonism is possibly hampered by décollement surfaces.

## METAMORPHISM

As a general rule the Cambrian sequence has been only slightly metamorphosed for if the effects of weathering and albite metasomation are omitted, the rocks have undergone little change. Locally, however, the Cambrian beds have undergone severe alteration as a result of the embayment of sulphides, mainly pyrite and chalcopyrite. This alteration involved sericitization, chloritization, propylitization and hydration and the resulting rocks are described as sericite and chlorite schists. At Mt. Lyell the process reached a peak and the West Lyell open cut area is the centre of an aureole of alteration extending outwards for three-quarters of a mile. As described in Wade and Solomon (1958) the auerole is very crudely zoned, the central sericite zone passing out to chlorite-rich areas and then to rocks that have undergone milder alteration which is included in the term propylitization.

Typical of the early, propylitic stage of alteration is a sheared feldspar porphyry (Q64) from the upper reaches of South Owen Creek. The feldspar phenocrysts are roughly aligned with the cleavage and are also slightly rounded, giving a poorly developed augen structure. The ground mass is a quartzose (?) microcrystalline aggregate almost obscured by thick sheaths of sericite (?) which lie parallel to the cleavage. Alteration of phenocrysts is in some cases slight but in others the feldspar is almost totally replaced by calcite growing from the crystal centres in reniform masses with dark rims. The initial phase of this alteration process is seen as the development of tiny calcite rhombs with parallel orientation throughout the feldspar crystals. Many other cases could be described but the complete treatment of the various types of hydrothermal alteration is the subject of another study.

The mineralization with which this metamorphic aureole is associated is of Devonian or Carboniferous age, as the sulphides are later than the Devonian cleavage and locally replace Junee Group rocks, and the remnants of basal Permian beds in the area are relatively undisturbed, have no cleavage and are unmineralized.

Other important areas of hydrothermal alteration apart from West Lyell are concentrated on the N-S line of copper deposits that mark the Great Lyell Fault Zone between Comstock and South Darwin.

Kaolinization of quartz porphyries is described by Bradley (1954, p. 233) near the Hospital at Queenstown and has been noted by the writer both south and north of Queenstown in small irregular zones. The alteration affects the entire rock apart from the quartz crystals and the result is a whitish or greenish clay that is studded with the residual quartz phenocrysts. The process appears to have no relation to mineralization and might in fact be a deuteric effect. It is selective in that if affects some porphyries but not others, yet no differences in environment, either structural or sedimentary, are discernible. Bradley, however, relates the kaolinisation to NE faults which he believes to be major controls over ore deposition.

## STRATIGRAPHY

The frequent lithological variations, the difficulties in elucidating structures and lack of fossils have prevented the establishment of a stratigraphic succession for the Group in this area. However, Bradley (1954, p. 221) has suggested the following sequence in the Lynch Creek area (youngest at the top):

| | feet. |
|---|---|
| Lynch Conglomerate .... .... .... | 3,000 |
| Battery Volcanics .... .... .... .... | 4,000 |
| Miners Slate .... .... .... .... .... | 3,000 |
| TOTAL .... .... .... .... .... | 10,000 |

The recent field work suggests that this succession has been measured across an anticline in which the Lynch Conglomerate and the "Miners Slate" occupy opposing limbs of the fold and are thus roughly equivalent (Fig. 3). The mapping has also shown that the lithologies change rapidly along strike and any sequence is therefore of only very local significance; this is at variance with the data on Bradley's maps which show the beds extending north and south of the type section for considerable distances. Part of Bradley's metasomatic hypothesis (1954, p. 224) is based on his belief that he could observe gradational metasomatism of the Lynch Conglomerate and Battery Volcanics along strike from Lynch Creek to Roaring Meg Creek. Actually the beds are not continuously exposed as his maps indicate, due to structural contortions (Fig 3); and in any case I would attribute the rock-type variations to original facies changes.

With regard to the terms Lynch Conglomerate, Battery Volcanics and "Miners Slates" the new structural picture renders suspect the proposed age relationships between these units, and other field evidence shows that whatever relationship may exist is likely to be a really restricted one. The rock types of the Dundas Group in this area, both volcanic and sedimentary, were almost certainly laid down in localized and ephemeral depositional environments and it is doubtful if contemporaneous depositon of any one rock type or particular association of rock types over a wide area ever took place. This being so, it would seem unwise at this stage to assign formational names to individual members of particular sequences that have been measured in this area and it is suggested that Bradley's terms be discarded. The terms he used are also unsatisfactory for other reasons, viz.:—

*Lynch Conglomerate*: I have been unable to match the description given for this formation with field observations and suspect that a considerable proportion of it is occupied by augite trachyte or trachytic tuff, which Bradley considered to be a conglomerate. This formation has been correlated with the Sorell Conglomerate and the Dora Conglomerate but the former is clearly part of the Jukes Formation and similar remarks probably apply to the Dora Conglomerate. The structural interpretation shown on Fig. 3 suggests the Lynch Conglomerate is equivalent in part to the Miners Slate and also that it is overlain unconformably by the Junee Group, both observations being at variance with Bradley's description.

*Battery Volcanics*: The age relationships are suspect and the locality name is unfortunate in that the "Battery" (of the King River Gold Mining Co.) is now non-existent and its position is seldom shown on published maps, new or old.

*Miners Slates*: Again the proposed stratigraphic relationship to the basalts is questionable and again the locality name could be improved; Bradley used the prefix "Miners" under the impression that the slates outcropped on Miners Ridge but as has already been mentioned (p. 44) this feature is due to the presence of a sandstone bed. In Wade and Solomon (1958, pp. 374-375) the terms Lynch siltstones and Miners sandstone (the capital 'S' in the 1958 text is a typographical error) were used as strictly lithological terms but this form of nomenclature is not now considered to be satisfactory, mainly because these terms are so similar to formation names and these carry so many implications. If it is desired to refer to the lithoiogies described under the terms Battery Volcanics and Miners Slates, and it is often convenient to do so during field work, then such terms as Lynch Creek-type volcanics and Lynch Creek-type slates could be used; similarly Crown Hill-type andesite, Whip Spur-type rhyolite, &c.

## THICKNESS OF THE DUNDAS GROUP

The only reliable reasurements available have been made near Little Owen and on Lynch Creek. The former area was mapped in conjunction with work on the Mt. Lyell Mine leases on a scale of 1" = 100 ft. and the measurements obtained are as follows: —

| | feet. |
|---|---|
| Conglomerates (?), pebbly sandstones and sandstones, probably partly volcanic, outcropping near Little Owen summit .... .... .... .... .... .... | 1,000 |
| Greywacke sandstones and tuffs, and augite trachyte (?) .... .... .... .... | 700 |
| Lynch Creek-type slates, exposed along South Owen Creek .... .... | 300 |
| "Dirty", fine grained sandstone .... | 500 |
| | 2,500 |

The rocks east of the Lynch Creek bridge are relatively undisturbed and they give the following sequence, measurements being by tape and level:—

| | feet. |
|---|---|
| Gordon Limestone .... .... .... .... .... | 600 |
| Owen Conglomerate (?): Grey-brown quartzite .... .... .... .... .... | 6 |
| Jukes Conglomerate (?): Grey to purple sheared paraconglomerate with pebbles of porphyry and sediments, and a few of quartz .... .... .... .... .... .... .... | 100-150 |

| | feet. |
|---|---|
| Dundas Group: Poorly exposed section; mainly finely and regularly banded pale grey shaly sandstone with lenses of paraconglomerate. Also lenticular quartz porphyry lavas, part kaolinised .... .... .... .... .... .... .... .... | 300 |
| Augite trachyte (?) .... .... .... .... .... | 250 |
| Basalts, tuffs and breccias .... .... .... | plus 1000 |

Total of Dundas Group exposed—1550 feet.

While drawing horizontal sections through the area it was found necessary to assume a thickness of at least 4,000 feet for the Group and generally a figure of twice this was used.

Hills (1914) suggests a thickness of 21,000 feet in the Jukes-Darwin area but he points out that the beds may be repeated by folding.

## THE DARWIN GRANITE

The Darwin Granite is the only large intrusive body in the area and it is of Cambrian age. Despite Bradley's assertions that it is Devonian, the occurrence of granite pebbles in the Jukes Conglomerate at South Darwin and at Mt. Sorell is clear proof that it is older than the Junee Group. The basal part of the Jukes Formation at South Darwin contains numerous and distinct sub-angular fragments (up to 24 × 30 cm.) of pink granite, white granite and haematitic material, together with smaller pebbles of quartz and chert (Plate 1, Fig. 2). The pebbles and fragments are clearly defined in a matrix of granitic detritus. In the Jukes Conglomerate exposed on the east face of Mt. Sorell the pebbles of granite and haematitic material are fewer in number and smaller in size.

The granite occurs as a vertical tabular body aligned north-south and extending from Mt. Darwin to South Darwin. Its outcrop is roughly three miles long and half a mile wide. The adjacent rocks to south and east contain pebbles of granite and are therefore younger but to the west and north consist of the pink potash rhyolites and tuffs, pre-granite in age.

The granite body is complex, being composed of parallel sheets of differing composition with a predominance of granitic types, chief of which are a pink orthoclase-quartz rock and a white plagioclase-quartz rock.

The *pink granite* (D42) forms a long line of tors on the eastern side of the Mt. Darwin-South Darwin Spur. It is coarse-grained and has a texture that is typically granitic, being not seriate yet not quite equigranular; intercrystal boundaries are commonly sutured. The mineralogy is simple, the only constituents being pink orthoclase, colourless quartz and pale green altered plagioclase feldspar and generally the mineralogical composition is orthoclase > quartz > plagioclase. However, in places the quartz content exceeds that of the feldspars and they occur in approximately equal quantity so that these varieties should be termed adamellites.

The orthoclase is fresh and most sections under the microscope show a fine, wispy cleavage; they often exhibit relatively coarse ("vein") perthitic texture, the orthoclase enclosing parallel tongues of plagioclase (albite ?) in which multiple twinning is perpendicular to the length of the tongues. Quartz crystals are finely fractured and show undulose extinction. The plagioclase is considerably altered to chlorite, kaolin and other minerals and its composition is difficult to determine but the few reliable measurements indicate a composition of $Ab_{92}$. Ferromagnesian minerals are rare and consist of ragged crystals of biotite and chlorite. The two available chemical analyses (Table 2, Nos. 1 and 2) resemble those of potassic granites.

The *white granite* (D40) occurs on the west flank of the pink variety; it is coarse-grained, locally almost pegmatitic, and is composed entirely of equal percentages of altered, cloudy plagioclase feldspar and colourless quartz. Alteration of the feldspar hampers identification but it appears to be oligoclase; its alteration products are whitish in colour in contrast to the greens of the plagioclase in the pink granite. The crystals are loaded with inclusions of quartz, suggesting it crystallized after that mineral. As with the pink granite, sutured crystal boundaries are characteristic. A chemical analysis of a specimen of this granite type, given in Table 2, No. 3, shows a reversal of the $K_2O/Na_2O$ ratio of the pink variety.

Workings for haematite and copper minerals in the granite prove that the alteration of the feldspars in both types extends many feet below the surface, indicating that it is not a weathering effect.

Within the granite complex are thin sheet-like tongues of sedimentary material trending parallel to the length of the granite. Between the pink and white granites is a long zone of schists showing patchy mineralization and in the pink granite occur dark-grey, sharply defined, hornfelsic lenses not unlike Lynch Creek-type slates; Bradley (1954, p. 325) emphasises the alternation of granite and hornfels by giving details of a traverse across the complex.

The outer margins of the granite are unfortunately not now exposed but Hills (1914) states that the "boundary-line between granite and the felsites which it has intruded is sharp and well-defined. This line of contact has been opened up in several places by trenching, and the granite can there be seen in contact with the felsite, being quite as coarse-grained as in the interior of the mass, no transition into finer grained varieties being observable at the margins". Certainly the felsites on the western side of the granite show little alteration that can be ascribed to granite intrusion, unless the unduly heavy haematite-magnetite veining is related to the granite.

A feature of the Darwin Granite is the complete lack of apophyses and aplite or pegmatite veins. This and other points such as the lack of contact matamorphism, complex composition and the tabular shape serve to distinguish it from the massive, irregularly shaped and monotonous stocks and batholiths of Devonian age such as occur at Mt. Heemskirk and Mt. Meredith. The Murchison Granite, which outcrops in the gorge south of Mt. Farrell, is similar in form to the Darwin Granite and even more variable in composition.

Though it has not been studied in detail, sufficient is known to indicate that it too contrasts with the Devonian granites and may well be of Cambrian age.

Bradley (1954) has suggested that the Darwin Granite is a replacement of sedimentary rocks but the evidence he presents, and the evidence since gathered by the writer, is insufficient to provide a conclusion on the mode of emplacement. However, the similarity in composition between the pink Darwin Granite and the potassic rhyolites, and between the white granite and the keratophyres suggests a genetic relationship. It is highly probable that the granites and the lavas represent the intrusive and effusive phases of a single late (?) Cambrian unwelling of acid magma, and that the granite core of the volcanic pile rose up at a late stage to become emplaced among the products of the earlier eruptions.

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TABLE 1

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 73.44 | 73.76 | 70.60 | 72.7 | 72.88 | 56.80 | 58.6 | 61.58 | 58.08 | 46.72 | 47.6 | 50.6 |
| $TiO_2$ | 0.33 | 0.12 | 0.40 | .. | 0.37 | 0.35 | n.dt. | 0.49 | 0.42 | 0.48 | .. | 0.5 |
| $Al_2O_3$ | 14.18 | 11.98 | 13.31 | 15.6 | 13.76 | 17.11 | 15.7 | 16.96 | 16.32 | 18.25 | 17.7 | 20.3 |
| $Fe_2O_3$ | 1.46 | 1.14 | 1.54 | Fe: 4.2 | 0.89 | 2.12 | 8.9 | 1.75 | 2.00 | 2.38 | 13.7 | 10.7 |
| FeO | 0.55 | 2.40 | 2.36 | .. | 3.44 | 5.26 | n.dt. | 2.85 | 5.53 | 7.73 | n.dt. | n.dt. |
| Mno | Tr. | .. | 0.05 | .. | 0.02 | 0.28 | n.dt. | .. | 0.12 | 0.07 | n.dt. | n.dt. |
| MgO | 0.43 | 0.76 | 1.75 | 0.9 | 0.94 | 3.61 | 3.6 | 3.67 | 3.98 | 7.81 | 6.55 | 4.4 |
| CaO | — | 0.32 | 1.68 | 0.4 | 0.16 | 4.20 | 2.8 | 6.28 | 7.32 | 7.86 | 8.2 | 6.6 |
| $Na_2O$ | 0.16 | 0.53 | 4.44 | 2.8 | 2.86 | 4.47 | 5.8 | 3.94 | 2.16 | 2.64 | 2.0 | 2.3 |
| $K_2O$ | 8.05 | 7.38 | 2.03 | 0.8 | 2.63 | 2.75 | 1.8 | 1.28 | 1.30 | 1.32 | 1.3 | 1.8 |
| $H_2O+$ | 1.38 | 1.65 | 1.46 | .. | 2.04 | 2.58 | 1.0 | 1.30 | 2.74 | 0.11 | 1.5 | 1.9 |
| $H_2O-$ | 0.08 | 0.10 | 0.06 | .. | 0.06 | 0.04 | | | Nil | 4.43 | | |
| $P_2O_5$ | 0.10 | 0.16 | 0.08 | .. | 0.09 | 0.35 | n.dt. | .. | 0.18 | n.dt. | .. | .. |
| $CO_2$ | 0.38 | — | 0.73 | .. | 0.31 | 0.44 | 0.7 | 0.25 | 0.38 | — | 0.6 | 0.4 |
| S | Tr. | 0.09 | 0.07 | .. | Tr. | Nil | n.dt. | .. | Nil | — | — | — |
| Other Consts. | .. | 0.09 | .. | 1.2 | (Ig. Loss) | .. | .. | .. | .. | .. | .. | .. |
| $SO_3$ | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1.1 | 1.0 |
| Total | 100.54 | 100.48 | 100.56 | 98.6 | 100.45 | 100.36 | 98.9 | 100.35 | 100.53 | 99.80 | 100.25 | 100.5 |

1. Potash rhyolite, Intercolonial Spur (near Mt. Jukes). Analyst: Tasmanian Mines Department, 1956.
2. Potash rhyolite, Cwm Caregog, Snowdon. Analyst: R. J. C. Fabry as qoted by Williams (1927, p. 368).
3. Quartz keratophyre, West Queen River. Analyst: Tasmanian Mines Department, 1956.
4. Analysis of rock from Lyell-Comstock tram line described by Gregory (1905) as "diabase porphyrite". Analyst: A. S. Wesley (quoted in Gregory, 1905).
5. Sodi-potassic rhyolite,-Lyell Comstock tram line. Analyst: Tasmanian Mines Department, 1956.
6. Keratophyre, Lake Margaret tram line. Analyst: Tasmanian Mines Department, 1956.
7. Augite trachyte (?), near Lynchford. Analyst: Mt. Lyell Co., Assay Office, 1954.
8. Hornblende andesite, Crown Hill. Analyst: Tasmanian Mines Department, 1956.
9. Hornblende andesite, Mount Shasta, California (H. N. Stokes), as quoted in Hatch, Wells, and Wells, 1949, p. 271.
10. Augite basalt from Lynch Creek, South Queenstown. Analyst: B. Scott (Unpublished Ph.D. thesis, University of Tasmania, 1953).
11. Augite basalt from Lynch Creek. Analyst: Mt. Lyell Co., 1956.
12. Basalt near Miners Ridge, east of Lynchford. Analyst: Mt. Lyell Co., 1956.

TABLE 2

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ .. .. .. | 74.96 | 71.9 | 76.92 |
| $TiO_2$ .. .. .. | 0.13 | n.dt. | 0.19 |
| $Al_2O_3$ .. .. .. | 13.55 | 14.7 | 14.07 |
| $Fe_2O_3$ .. .. .. | 0.79 | 3.6 | 0.43 |
| FeO .. .. .. | 0.71 | n.dt. | 0.64 |
| MnO .. .. .. | 0.01 | n.dt. | Tr. |
| MgO .. .. .. | 0.48 | 0.6 | 0.25 |
| CaO .. .. .. | 0.16 | 0.5 | 0.16 |
| $Na_2O$ .. .. .. | 2.33 | 1.9 | 3.24 |
| $K_2O$ .. .. .. | 5.57 | 4.7 | 2.61 |
| $H_2O+$ .. .. .. | 0.86 | 0.6 | 1.84 |
| $H_2O-$ .. .. .. | 0.16 | | Nil |
| $P_2O_5$ .. .. .. | 0.05 | n.dt. | Tr. |
| $CO_2$ .. .. .. | 0.30 | 0.4 | 0.06 |
| Total .. .. | 100.06 | 98.9 | 100.41 |

1. Pink granite, South Darwin. Analyst: Tasmanian Mines Department, 1956.
2. Pink granite, South Darwin. Analyst: Mt. Lyell Company, Assay Office, 1955.
3. White granite, South Darwin. Analyst: Tasmanian Mines Department, 1956.

Plate I.

Fig. I.—Albitised hornblende andesite from Crown Hill. The pale grey rock is largely fresh albite, the darker grey is hornblende-feldspar porphyry.

Fig. II.—Jukes Conglomerate, South Darwin Peak. The boulders to the right of the hammer are pink granite; the large one to the left is haematitic schist. The lack of contrast between boulders and the matrix is due to inadequate lighting of the subject at the time of photography.

# EUCALYPTUS IN IRELAND

By

D. MARTIN*

(With 4 Figures)

## HISTORY.

The first introduction of Eucalyptus into Ireland probaly took place about the middle of the 19th Century. Elwes and Henry (1906-13) refer to planting of *E. coccifera*† in 1840, *E. gunnii* in 1841, and *E. globulus* in 1852. There is still one tree of that era alive, an *E. globulus* at Garron Tower, Co. Antrim. This was planted in 1857 (Wilson 1949), probably from seed of South African origin, by the second wife of the third Marquess of Londonderry who succeeded to the property and died about 1860.

Most of the present large trees date from the second period of planting (1870-1910) when owners of large estates planted specimen trees as objects of curiosity. It is the survival of such trees in the British Isles which has given most of the information on frost hardiness in the genus. [Martin (1948) Wood (1957).]

The success of these specimen trees led to the first official trial for forestry purposes. In 1908 the then Director of Forestry in Ireland procured from the Government of Tasmania small packets of seed of:—

*E. subcrenulata* (then called *E. muelleri*);
*E. urnigera;*
*E. coccifera;*
*E. ovata* (then called *E. gunnii* under the mistaken idea that the former was a lowland form of the latter).

Forestry in Tasmania was at that time an appendage of the Department of Lands and seed was collected from the handiest places, Mt. Wellington, and no attempt was made to get seed of the hardiest or best growth form strains. Later, seed of the commercial timber species *E. gigantea* and *E. regnans* was imported.

These were planted at the Forestry Station at Avondale, Co. Wicklow, and did so well that in 1934, 1935 and 1937 much bigger plots were set out at the State Forest at Ballymanus, Co. Wicklow, using seed from local Irish trees and seed from New Zealand. The species included *E. amygdalina, E. dalrympleana, E. gigantea, E. johnstoni, E. subcrenulata* (as *E. muelleri*), *E. radiata, E. urnigera, E. viminalis,* (mountain and coastal). Another small planting of *E. subcrenulata* (as *E. muelleri*) and *E. viminalis* was made at Delgany Forest.

The reason for using seed of New Zealand rather than Tasmanian origin could not be ascertained. Also the provenance of the mountain and coastal forms of *E. viminalis* is unknown. They must have been from mild habitats for both were soon killed, as were *E. regnans* and *E. globulus.*

In 1942 a further small quarter-acre plot of *E. subcrenulata* (as *E. muelleri*) and *E. urnigera* mixed with a few *E. viminalis* and *E. ovata* (genuine *E. ovata* not *E. gunnii*) was planted at Avondale.

In 1948 a much bigger experiment was planned; seed of 18 species was obtained from the Forestry Commission of N.S.W. and planted out at Avondale in 1950.

These were:

| | | |
|---|---|---|
| *E. bicostata* | *E. dives* | *E. mannifera* |
| *E. blakelyi* | *E. elaeophora* | *E. obliqua* |
| *E. cinerea* | *E. fastigata* | *E. pauciflora* |
| *E. cordieri* | *E. fraxinoides* | *E. phellandra* |
| *E. dalrymple-ana* | *E. gigantea* | *E. rubida* |
| *E. dealbata* | *E. goniocalyx* | |
| | *E. huberiana* | |

By 1953 only a few trees of *E. mannifera, E. rubida, E. bicostata* and *E. phellandra* survived, but the mortality was thought to have been due to causes other than climate. The trial was repeated at Killarney Forest, Co. Kerry, which was milder than Co. Wicklow, with the same species except for *E.goniocalyx, E. elaeophera, E. dealbata, E. pauciflora,* and *E. fastigata* which were omitted. The seedlings received very great care and were put out in moss balls and lined out under light shade in September, 1955. The losses mounted and all were finally killed by a severe frost in January, 1956.

This unfortunate result may have been due as much to the over careful nursery practice, in which the seedlings were weakened by rapid growth and inadequate light, as to the use of seed of N.S.W. origin of lower potential frost resistance and probably higher light requirement. These failures were in marked contrast to the earlier and simpler plantings at Avondale and Ballymanus which were predominantly of Tasmanian species.

O'Beirne (1945) reported that the 1909 plantings at Avondale had grown as indicated in Table I.

TABLE I

| | Average Height feet | Q.G.B.H. inches |
|---|---|---|
| *E. subcrenulata* (as *E. muelleri*) .... .... .... .... | 108 | 13½ |
| *E. urnigera* .... .... .... .... | 108 | 12½ |
| *E. coccifera* .... .... .... .... | 73 | 11½ |
| *E. ovata* .... .... .... .... .... .... | 107 | 12½ |

* Lecture given to the Royal Society of Tasmania on 7th April, 1959.

† No authorities are quoted for botanical names because of frequent lack of opportunities for critical identification and the great variability of certain species.

Only *E. ovata* had been damaged by frost. Of the later plantings, *E. gigantea*, *E. subcrenulata* (as *E. muelleri*) and *E. urnigera* were growing vigorously.

Of the Ballymanus plantings, O'Sullivan (1957) reported the dimensions shown in Table II.

| Planted | Species | Average Height 1954 feet | Q.G.B.H. inches |
|---|---|---|---|
| 1934— | | | |
| | *E. subcrenulata* (as *E. muelleri*) | 56 | 6¼ |
| | *E. radiata* | 51 | 5 |
| | *E. urnigera* | 55 | 5¾ |
| | *E. dalrympleana* | 48 | 6 |
| | (*E. viminalis* had been practically exterminated) | | |
| 1935— | | | |
| | *E. urnigera* | 51 | 5¾ |
| | *E. subcrenulata* (as *E. muelleri*) | 59 | 4¾ |
| | *E. gigantea* | 46 | 5¾ |
| | *E. johnstoni* | 48 | 6¼ |
| | (*E. viminalis and E. amygdaline* also killed out). | | |
| 1937— | | | |
| | *E. subcrenulata* (as *E. muelleri*) | 61 | 6¼ |
| | *E. urnigera* | 59 | 5¼ |

The Ministry for Agriculture in Northern Ireland has recently commenced experiments with Eucalyptus at Gosford, Castleward and Tollymore Park. The behaviour of specimen trees at Castlewellan, Rowallane, Newcastle, Rostrevor, Narrow Water, Bangor and Mt. Stewart suggest that even moderately hardy species may be useful in Co. Down at least.

The first comprehensive list of Eucalyptus species in Ireland was that of Fitzpatrick (1933) and the following is an attempt to bring this up to date and to include records of all trees which have survived for the past 20 years. This period includes two very severe winters 1939 and 1947. The fate of those trees recorded by Fitzpatrick is indicated by [Fitz. (+) alive 1957; (—) not surviving], followed by new records. These do not claim to be exhaustive, but are as complete as a short visit to most centres in 1957 and correspondence have permitted.

*E. amygdalina* [Fitz. Shelton Abbey (—)]. Ballymanus, Co. Wicklow.

*E. coccifera* [Fitz. Kilmacurragh (—); Mt. Usher (+); Rossdohan (+); Fota Is. (+); Rowallane (—); Daisy Hill (—); Rostrevor (+ 1948); Old Conna Hill (+); Avondale (+)]. Slingers Newcastle, Co. Down.

*E. cordata* [Fitz. Narrow Water (+); Castlewellan (+); Kilmacurragh (+ recorded as *E. pulverulenta*); Rostrevor (1948) (also another form resembling *E. biangularis*)]. Fota Is., Co. Cork.

*E. dalrympleana* Ballymanus.

*E. gigantea* [Fitz. Mt. Usher (+)].

*E. globulus* Ballymanus; Avondale. [Fitz. Dinas Island (+); Dereen (+); Rossdohan (+); Garrettstown (+?); Glenstal (—); Clonmannon (+); Bangor Castle (+); Rostrevor (+); Tollymore Park (—); Shelton Abbey (—)].

*E. gunnii* Glen of Downs, Co. Wicklow; Ballywater Park, Co. Down; Mt. Stewart, Co. Down; Garron Tower, Co. Antrim; Laughlinstown, Malahide Castle, Co. Dublin; Kenmare, Co. Kerry; Kinsale, Cobh, Glengariff, Fota Is., Co. Cork. (Note: Two forms exist in Ireland, a highly glaucous type (G) absent from Britain, and a non-glaucous type (N.G.) similar to that planted widely in Britain). [Fitz. Kilmacurragh (—); Narrow Water (—); Daisy Hill (—); Rostrevor (+ 1948]. Glenstal Abbey, Co Limerick (N.G.); Glasnevin, Co. Dublin (G. and N.G.); Brook Hall, Co. Londonderry (N.G.); Garinish Is., Co. Cork (G. and N.G.); Mt. Stewart, Co. Down; Fota Is., Co. Cork; Castlewellan, Co. Down (N.G.).

*E. ovata* (Note: This has been called *E. gunnii*, lowland form, or *E. acervula* or *E. stuartiana*, the latter sometimes corrupted to *E. stuartina*). [Fitz. Narrow Water (—)]. Avondale, Co. Wicklow; Slingers, Newcastle, Co. Down; Fota Is. (?).

*E. linearis* Rowallane; Mt. Stewart, Co. Down; Rossdohan, Co. Kerry.

*E. pauciflora* [Fitz. Rostrevor (+ 1948); Rossdohan (—)].

*E. regnans* [Fitz. Mt. Usher (+) seedling from original tree killed].

*E. pulverulenta* [Fitz. Mt. Usher (+); Kilmacurragh (—)]. Fota Is.

*E. radiata* Ballymanus.

*E. subcrenulata* (as *E. muelleri*) [Fitz. Direen (+); Mt. Usher (+); Avondale (+ 1945); Rostrevor (+ 1948)]. Fota Is.; Ballymanus; Delgany.

*E. johnstoni* Mt. Usher; Ballymanus.

*E. urnigera* (Note: The non-glaucous type only, none of the glaucous type has been found anywhere in Ireland). [Fitz. Mt. Usher (+); Avondale (+); Rowallane (+); Castlewellan (+); Rostrevor (+ 1948)].

*E. viminalis* Fitz. Mt. Usher (+); Avondale (—); Rossdohan (—); Rostrevor (—)].
*E. vernicosa* Rostrevor (1948).

There is a tree at Mt. Usher named *E. beauchampiana* by A. Henry who later corrected it to *E. stuartiana**. E. M. Davey in 1948, using Blakely's key, considered it was more likely *E. viminalis*. He raised seedlings which proved to be variable. Leaves of the three types were supplied by Sir Edward Salisbury to R. G. Brett who considered that the parent tree might be of a *rubida-viminalis* swarm.

Material collected in 1957 showed that though the capsule is not similar to the normal *viminalis* type and it does resemble that of *E. stuartiana* in its spherical-truncate shape and widely protruding valves but, unlike that species, the buds are in threes and the habit of the tree and its progeny now growing at Mt. Usher are very like *E. viminalis*.

The original seed was sent from Tasmania to Rostrevor, Co. Down, for Sir John Ross of Bladensburg in 1901 and later sent to Mt. Usher from there. This species has since died out at Rostrevor. As *E. stuartiana* does not occur in Tasmania this specimen must be an *E. viminalis* product.

## CLIMATIC COMPARISON

It will be seen from the above record thta it is predominantly the Tasmanian Eucalyptus which have been successful in Ireland, and this may be linked with the similarities of climate. In both islands it is maritime with a very wet West coast and a drier East coast. In water regimen, the differences lie in evaporation rather than in precipitation. As a whole, Ireland receives 50 inches annually (with very little having less than 30 inches), and has an evaporation of only 15 inches, while Tasmania has a similar average precipitation, 46 inches for the whole State (with about one-quarter having less than 30 inches) but roughly twice the evaporation (30 inches) for most of the State falling to 20 inches in the high rainfall areas of the west. Sunshine in Ireland is approximately two-thirds that of Tasmania.

This reduced evaporation naturally produces large areas of bog quite unsuited to Eucalyptus, which require well aerated soil, but the drier parts of Ireland provide conditions comparable with the moderately wet parts of Tasmania and the two islands have large areas with a common water regimen and potentially common habitats for the more moisture tolerant species. One half of Tasmania and all of Ireland have a mean anual 9 a.m. humidity of above 75%. This is not a satisfactory basis for comparison but does suggest similarity of humidity for certain areas.

Apart from drainage, the chief factor limiting the survival of Eucalyptus is the absolute minimum temperature. The length of time a particular species will survive is dependent on the chances that a killing frost for that species will occur.

* *E. stuartiana* = *E. bridgesiana.*

The history of the cultivation of Eucalyptus in Britain and Ireland is of successful growth for a number of years terminated suddenly by an unusually severe frost. The number of frosts is of less importance though a series of milder frosts can be as fatal as a single severe one.

As a result of a series of such meteorological calamities one can divide the Tasmanian Eucalypts into four groups according to the minimum temperature they can survive as adults.

0-5°F. *E. gunnii; E. vernicosa.*
5-10°F. *E. coccifera; E. urnigera; E. subcrenulata* (as *E. muelleri*); *E. simmondsi* (high altitude); *E. pauciflora* (high altitude).
10-15°F. *E. gigantea* (high altitude); *E. rubida; E. dalrympleana; E. ovata* (high altitude); *E. aggregata; E. cordata; E. amydgalina* (high altitude); *E. viminalis* (high altitude); *E. johnstoni.*
15-20°F. *E. globulus; E. obliqua; E. regnans; E. linearis; E. perriniana; E. sieberiana.*
20-25°F. *E. risdoni; E. tasmanica; E. morrisbyi.*

An attempt has been made to compare the temperature regimen of Ireland and Tasmania in the following diagrams which have been prepared from the Climatological Atlas of the BritishIsles(1952) and the limited data available for Tasmania from the Bureau of Meteorology, Hobart*.

### (1) Absolute minimum Temperature

In comparing the two maps it can be seen that for a 40-year period no place in Ireland had a frost below 5°F. and except for the central region temperatures have not fallen below 10°F. and for a wide belt round the coast 15°F. is the minimum. Tasmania has many similarities. On the northern coasts the area of 20°F. min. is wider for Tasmania and the central area with a possible frost below 10°F. probably smaller, but in both islands there are large areas between the 10° and 20°F. lines. Oatlands has the lowest recorded temperature of 9°F. but the big freeze of 1835 which killed large areas of Eucalyptus in the Upper Derwent Valley may have been of the order of 5°F.

### (2) Average Frequency of Frost

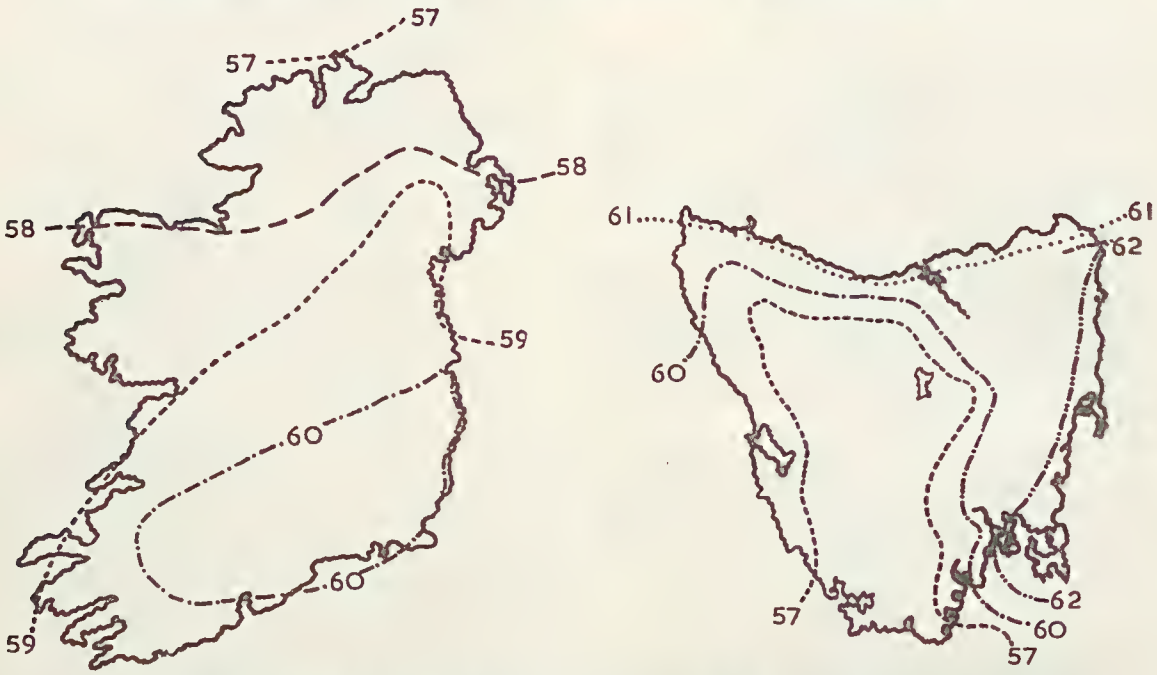
The islands have areas of similarity, but Ireland has more frost near the coasts.

### (3) Average Daily Mean Temperature, Midsummer and Midwinter

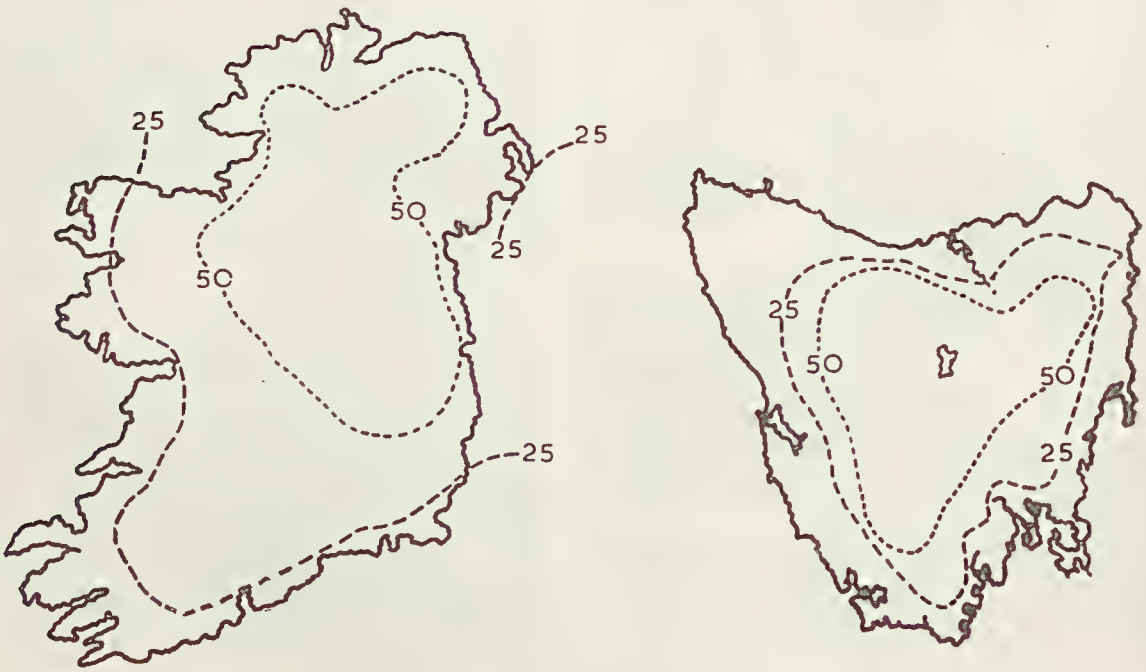
Again there are areas of similarity, nearly all of Ireland and two-thirds of Tasmania have a midwinter daily mean below 45°F. and one of Ireland but one-third of Tasmania a midsummer daily mean below 57°F. In fact the climate of the Tasmanian S.W. and West Coast are probably very similar to those of Kerry and Connemara. The interior of Ireland has probably a similar climate to that of Waratah or Gormanston, Tasmania.

* The author desires to emphasise that these diagrams are his own interpretation of probable conditions in Tasmania for the purpose of demonstrating probable similarities; they do not pretend to be authoritative.

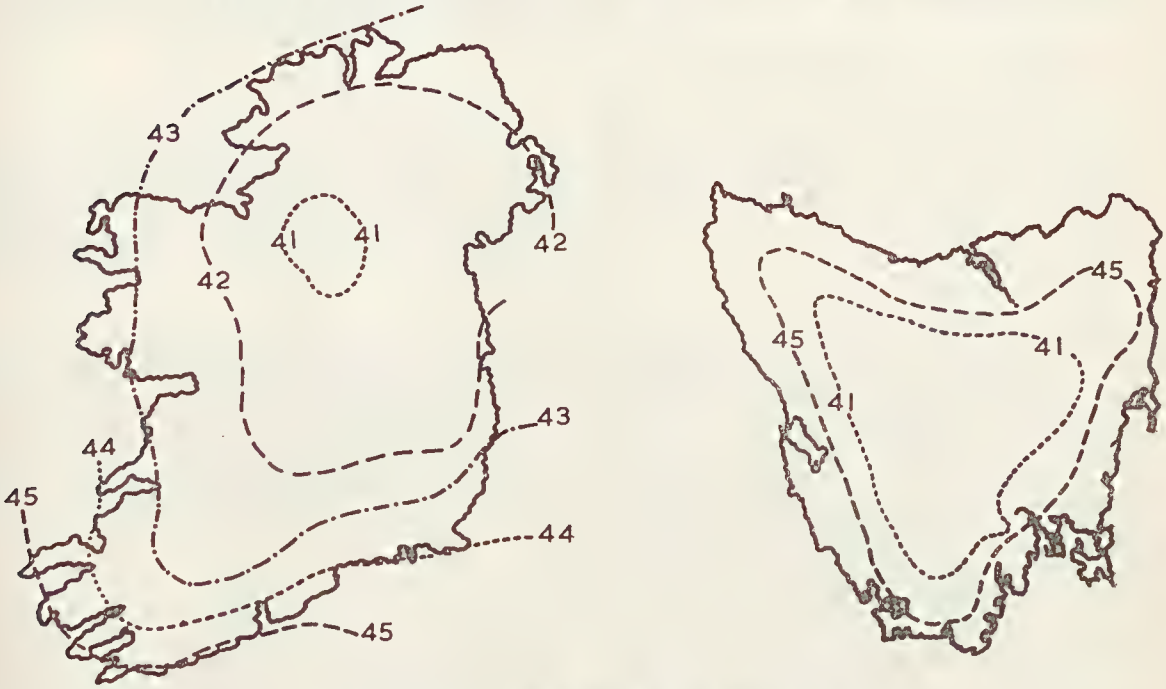
## AVERAGE DAILY MEAN TEMPERATURE, MID-SUMMER



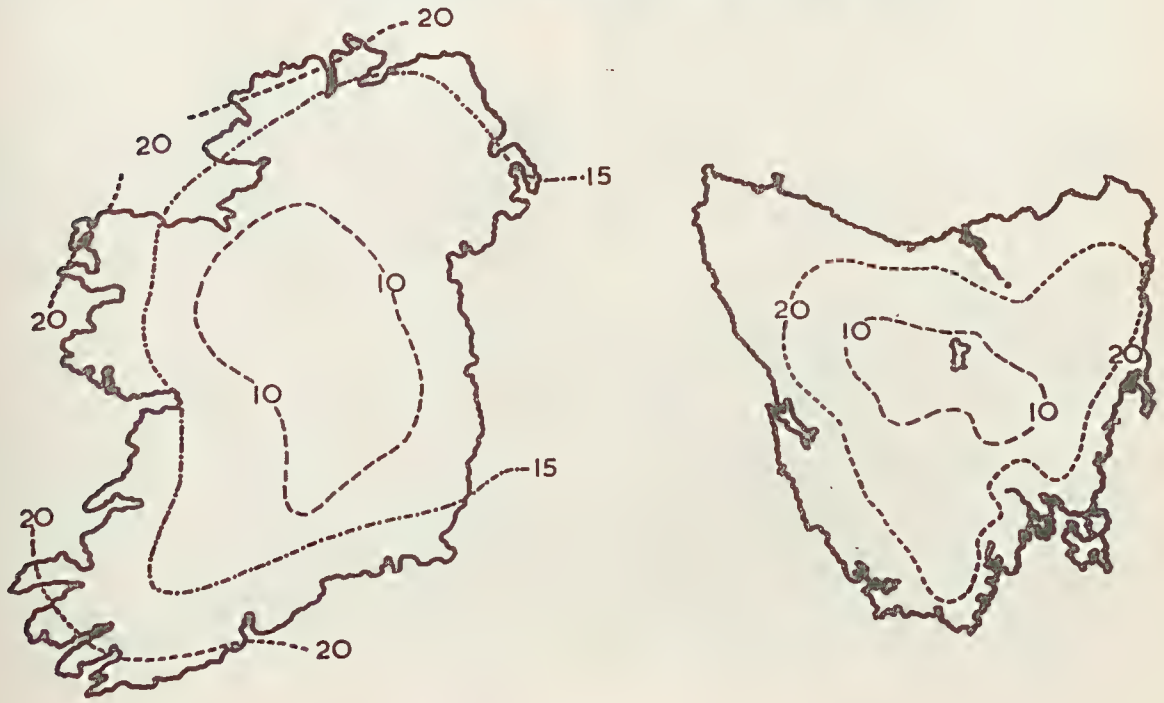

## AVERAGE ANNUAL NUMBER OF DAYS WITH 32°F OR LESS



## AVERAGE DAILY MEAN TEMPERATURE, MID-WINTER




## ABSOLUTE MINIMUM TEMPERATURE



Gormanston in Co. Wicklow Ireland, has certainly a less unpleasant climate than its namesake in Tasmania.

These similarities are confirmed by the survival of Eucalyptus. The relatively tender species *E. globulus* may be found as quite old trees at many places round the coast from N.E. to S.W., and the hardy species *E. gunii, E. urnigera, E. coccifera* and *E. subcrenulata* (as *E. muelleri*) over the area between the 10° and 15°F. lines of Fig. 1 *E. cordata, E. gigantea, E. pauciflora, E. johnstoni, E. ovata* and *E. linearis* also survive in this region.

No evidence could be found that the genus had been tried within the 10°F. lines.

Private cultivation has suffered from the decline of the large country mansion, but the collection of Mr. E. H. Walpole of Mt. Usher is still maintained and presents a magnificent sight with trees of *E. urnigera, E. johnstoni, E. gigantea* and *E. stuartiana* towering 100-150 ft. (Plate 1).

Further experiments will be made in Southern Ireland and there is no reason why carefully selected provenances of *E. gigantea, E. coccifera, E. urnigera* and *E. subcrenulata* (as *E. muelleri*) should not provide a useful contribution to forestry over quite a wide area in the East and South for strong structural timber and poles. *E. simmondsi* might find a useful place even on the West Coast.

## ACKNOWLEDGMENTS

It is desired to acknowledge the help and information supplied by many contacts and correspondents all over Ireland and, in particular, Mr. S. M. O'Sullivan, Inspector General, Department of Lands (Forestry Division) Dublin, Dr. T. J. Walsh, Curator of the National Botanic Gardens, Glasnevin and Mr. E. H. Walpole of Mt. Usher.

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# NOTES ON THE INTERTIDAL ECOLOGY OF TRIAL HARBOUR, TASMANIA.

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(With 3 plates)

1. Introduction.
2. Description of Area.
3. Methods and Nomenclature.
4. The Physical Environment.
5. Ecology of the Reef.
6. Notes on nearby Areas.
7. Discussion.
8. Acknowledgements.
9. References.

## ABSTRACT

A description is given on the zonation and general ecology of a reef on the exposed West Coast of Tasmania. The reef shows the unusual feature of a *Hormosira-Corallina* belt on an exposed coast. A white species of *Lithothamnion* which is considered to be characteristic of cold water conditions occurs there. The scarcity of littorines and barnacles is attributed to local factors.

## 1. INTRODUCTION

This paper is the eleventh of a series on the intertidal ecology of Tasmania and is the first to describe the major features of an intertidal region on the West Coast of Tasmania. This coastline is very rugged and is readily accessible at only four places. The most southerly accessible place, West Strahan, is a region of sandy beach and is thus outside the scope of this present series of papers. The north-westerly part of the coast is fairly readily accessible but is situated a considerable distance from Hobart. An attempt was made to examine the shore at Pieman Heads, a difficult place to reach, but bad weather defeated my object. The site of the present study, Trial Harbour, latitude 41° 59′ S. longitude 141° 10′ E., is accessible by motor track from Zeehan. Visits were made to the harbour in January, 1951, November, 1956, and February, 1957 and February, 1958. Trial Harbour is named for the brig "Trial" which used the "port" for the first time in 1881. During the mining boom the region became the site of the town of Remine and a jetty was erected. Little remains of either structure today. The place is well named since clouds of sandflies, mosquitos and frequent very rapid changes of weather make working there a real trial.

## 2. DESCRIPTION OF THE TRIAL HARBOUR AREA

Trial Harbour, latitude 41° 59′ S., consists of a reef extending a few chains out to sea in a north-westerly direction and some smaller reefs along the coast with boulder beaches. The roadstead is narrow.

To the north of Trial Harbour the coastline consists of rocky cliffs trending generally in a north-westerly direction. The cliffs are only feebly incised by watercourses and there are few boulder beaches. To the south of Trial Harbour there are three low rocky headlands interspaced by beaches. The beaches are composed of yellow quartzose rounded grit fragments forming a rather soft gritty sand. The hard packing of sand found on many ocean beaches is lacking here. There was evidence in November, 1956, of a very considerable removal by marine agencies of sand from one beach to the south of Trial Harbour. At one end of the beach a vertical bank seven feet in height had been cut in the grit, indicating that this quantity of substratum had been removed fairly recently. The sand scouring experienced by intertidal organisms must be intense.

To the south beyond the furthest of the headlands mentioned above, the shoreline continues for 15 miles to Macquarie Harbour as Ocean Beach, a sand surf beach penetrated near its northern end by the Little Henty River.

## 3. METHODS AND NOMENCLATURE

The area was examined during three periods, namely January, 1951, November, 1956 and February, 1957. During the first of these visits the weather encountered was so bad that little work beyond a preliminary survey could be undertaken, but better success was obtained on the later visits.

The collections were sorted and I am indebted to Mr. R. C. Kershaw and Miss Hope Macpherson for identifying the Mollusca and to Dr. Dora P. Henry for naming the Cirripedia. The algae were identified from University Herbarium material.

The nomenclature used is that of Stephenson and Stephenson (1949) and Guiler (1953).

The author of each species is only quoted in the text the first time that species appears.

## 4. PHYSICAL ENVIRONMENT

### (a) Climatic factors.

(1) *Rainfall.*—The Trial Harbour area is shown by the Weather Bureau (1936) to be in an area of 50" to 60" annual precipitation. This rainfall is seasonal with more than 5" occurring each month during the period April to October, inclusive.

There is no meteorological station maintained at Trial Harbour or in its vicinity so there are no records of temperatures, relative humidity or other climatic data. However, the Meteorological Office (1947) shows the region as having a mean monthly temperature range from 20°C. to 6.6°C.

### (b) Sea temperatures.

There are no sea temperatures available from Trial Harbour but the Meteorological Office show the West Coast of Tasmania as having a maximum monthly sea temperature in March of 18.8°C. and a minimum of 9.4° in September.

### (c) Wind and Swell.

The prevailing wind at Trial Harbour is westerly to north-westerly with the latter being the sector of strongest winds. The winds reached Force 7 (Beaufort Scale) during 10% of the observations recorded by the Meteorological Office (1947). The swell is prevailing south-westerly to southerly with heavy swell occurring some 10% of the time and a moderate swell being the usual type of sea encountered. Days or no swell are rare. All of these records were compiled by ships off the coast and may not reflect conditions on the shore. For example, strong north to east, i.e. offshore winds deaden the effect of swell and reduce very materially the amount of wave action on the shore.

Briefly, to sum up the physical environment, Trial Harbour experiences a considerable range of temperatures, both air and sea, and has a heavy rainfall. Rough seas together with heavy to moderate swells are liable to occur at any time during the year and gales are frequent.

### (d) Geology.

Waterhouse (1916) describes the geology of the area in detail. The coastline to the north of Trial Harbour consists of a red granite with some metamorphosed sedimentary rocks near the harbour. Similar metamorphic rocks exist to the south of the Harbour and form small headlands. The reef at Trial Harbour is composed of serpentine which when fresh, is a very dark blue but on the reef it is soft in texture and coloured a light greenish grey. Waterhouse considers that the freshest reef rocks are a light brown colour. The reef is penetrate by veins or aragonite and contains magnetite.

Wave action has worn the reef down to a very uniform level with a ridge at one point near the seaward edge. There are extensive deep gullies worn in the edges of the reef and at low tide the general reef surface has ponds which are usually fairly shallow (10 cms. approx. depth). The reef is entirely covered at high tide or during periods of rough seas.

In Tasmania, where much of the coastline consists of dolerite which does not form wave cut platforms of any extent, large reefs such as this are uncommon. The largest platforms I have seen are at South Cape Bay where the reef extends over 100 feet from the base of the cliffs.

Fresh water enters the harbour near the reef where the Serpentine Creek pours into the sea. Except at times of flood the volume of water carried by the Creek is not great but even then it is doubtful if it could have a profound effect on the fauna and flora because it enters the Harbour at a deep water channel which is always stirred up by wave action. Biologically, as shall be seen below, there is little evidence of the fresh water having any effects on the animals and plants. There are several other sources of fresh water ranging from seepages to creeks between Trial Harbour and the Cliff Mine, but as at Trial Harbour, they do not have any apparent effect on the fauna or flora of the shore. All these creeks carry brown button-grass water.

## 5. ECOLOGY OF THE REEF

The reef, as noted above, is remarkably uniform in the level nature of its surface and as a result, most of it falls in one characteristic faunal and floral belt. The exceptions to this are at the edges of the reef, whether exposed to the full effect of wave action or not, on some slightly elevated rocks at the wave sheltered end of the reef and on a small raised ridge at the seaward exposed end of the reef.

The zonation seen on the rocks at the sheltered end of the reef is—

*Chamaesipho columna* (Spengler)
*Siphonaria diemenensis* (Quoy and Gaim.);
*Hormosira banksii* (Turn.) Decaisne + *Corallina* sp.

There are no further belts below this level because the Infralitoral fringe and the lower parts of the Midlittoral are replaced by ponds. Most of the reef, however, falls into this mixed *Hormosira-Corallina* belt. In November the *Hormosira* plants were all small and obviously young growths. The November visit showed a very well developed belt below *Siphonaria* consisting of *Scytosiphon lomentarius* (Lyng.) J. Ag. and *Elachista* sp., together with *Colpomenia sinuosa* (Roth.) Derby & Sol. and a few *Ulva* plants. I do not include this algal belt as a permanent feature of the zonation as all these species are noted for the seasonal nature of their presence on the shore and in February they were absent.

### (a) The *Chamaesipho* belt.

In sun shaded places the lower parts of the *Chamaesipho* belt have a population of *Galeolaria caespitosa* (Lam.). This worm never reaches the status of a belt forming species, but it is common in situations similar to that described above.

The *Chamaesipho* belt does not support a well developed fauna or flora. There are no lichens or algae at this level on the shore. The absence of lichens is undoubtedly due to the fact that the rocks do not reach sufficiently far above the inter-

tidal region for the Supralittoral lichens to appear. The absence, rather surprisingly, of the littorinid, *Littorina unifasciata* (Gray), can be attributed to the same cause. Most of the species encountered are cryptic in habit. One of the most interesting of these is the small mussel *Modiolus pulex* Lam. which is characteristically surrounded by sand which clings to the shell. These tiny mussels, approximately 2 mm. in length live in cracks in the rock and although very numerous, are most inconspicuous.

The other species found in the barnacle belt are the gastropods *Subninella undulata* (Solander), *Melanerita melanotragus* (Smith), *Lepsithais vinosa* (Lam.), *Fossarina* sp.? *legrandi* Petterd, *Siphonaria diemenensis* (Quoy and Gaim.), *Montfortula rugosa* (Quoy and Gaim.), the mussel *Modiolus pulex* Lam. and the chiton *Sypharochiton maugeanus* Iredale and May. All of these above species favour sun shaded places. *Montfortula rugosa* is scarce in this belt. It was surprising to find a young *Cellana solida* (Blainville) in this belt. *Notoacmea petterdi* (Ten.-Woods) and *Conacmea subundulata* (Angas) also are found in the *Chamaesipho* belt as well as *Siphonaria zonata*.

*Chamaesipho* belt occurs at the seaward edge of the platform where there is a ridge of rock elevated above the general shelf level. This belt is populated by *Notoacmaea mayi, Lepsithais vinosa, Littorina unifasciata, L. praetermissa*. Permanent ponds in this belt have a sandy mud bottom with *Subninella undulata, Dicathais textiliosa*, and the tectibranch *Pleurobranchus maculatus* (Quoy and Gaim.), Miss Nielson, who identified this species for me, assures me that the specimens do not fit Quoy and Gaimard's original figure but that they belong to the species usually considered as *P. maculatus*.

(b) **The *Siphonaria* belt.**

The dominant species is *S. diemenensis* together with the small sand surrounded mussel of the *Chamaesipho* belt, *Modiolus pulex*. *Ulva lactuca* and *Scytosiphon lomentarius* are common in restricted areas which have a small amount of water retained on them at low tide. However, these growths are seasonal, being absent from the reef in February. The lower part of the *Siphonaria* belt is characterized by a rich growth of *Scytosiphon* + *Ulva* + *Elachista* with *Colpomenia sinuosa*.

Ponds in this belt contain *Subninella undulata*, small plants of *Ecklonia radiata* (Ag.) J. Ag., a few *Corallina* sp., and a sparse population of *Enteromorpha* sp. on sun sheltered damp situations. A deep pond in this belt contained a large number of *Subninella, Gigartina* sp., a large orange nudibranch, *Dicathais baileyana, Colpomenia sinuosa, Ecklonia radiata, Corallina cuvieri, Tethya diploderma* (Schmidt), *Hymeniacidon perlevis* (Montagu). Below a large stone in the pond was a *Botryllus* sp., orange in colour, a deep plum coloured *Botrylloides*, a purple *Lithothamnion* and a bright orange-red calcareous *Bryozoan*.

Other species found on the rocks in this belt are the limpets *Notoacmea petterdi* (Ten.-Woods), *Conacmea subundulata* (Angas), a species of *Chiazacmea*, the pulmonate *Siphonaria tasmanica* (Ten.-Woods), the therid *Lepsithais vinosa* (Lam.) and the chiton *Sypharochiton maugeanus* Iredale and May. The latter species is especially common in clefts and in ponds.

(c) **The Hormosira-Corallina belt.**

Most of the reef falls into this belt which continues as far as the algal belt at the seaward edge of the reef. The continuity of the belt is broken by ponds, some of which are of considerable size but mostly of shallow depth, being less than one metre deep at low water.

The ponds contain a similar algal flora to that described above, namely *Ecklonia, Colpomenia* and *Corallina* with the addition of *Phyllospora comosa* (Labill.) Kutz., *Laurencia botryoides* (Turn.) Gail., *Codium fragile* (Sur.) Hariot, *Corallina pilulifera* Post & Rupr. An interesting feature of these ponds is the presence in them of small plants of *Macrocystis pyrifera* (L.) Ag. This species is usually found living in offshore beds and is not usually a species of the intertidal zone. However, although some of the small plants living in the ponds are never exposed to the air and so cannot be considered as intertidal in nature, other larger plants living in the big ponds are exposed for considerable periods at low water and so can be considered to be intertidal in nature (Plate I). *Hormosira banksii* occurs around the edges of all of the ponds. All of these algae are of equal ecological status with the exception of *Codium* which is scarce.

The fauna of the deeper ponds is poor. This is in large measure due to the absence of the stones on the bottom of the ponds to provide shelter for a cryptic or semi-cryptic fauna. There are several very large boulders which undoubtedly shelter some animals but they are too large or too solidly embedded to move. A further factor, probably the most important, which discourages the development of a large fauna is the nature of the bottom of the ponds. The bottom is of sand which is moved about considerably during gales and must move to some extent during the normal period of the day when the shore is covered by the sea. There is no infauna in the sand.

The starfish, *Patiriella calcar* (Lam.) is locally very common in ponds. In some places up to 100 individuals can be collected in an area of about one square metre. It is particularly numerous in places where there is some drift weed. This species is very variable in colour and the number of animals found each day also varies very considerably. On 6th November, 1956, there were many *Patiriella* in the ponds but on the following day the species was uncommon. Searching did not reveal the hiding places of the animals. By the 8th, the starfish had returned and there were plenty of them in the ponds.

Other species found in the deeper ponds are *Dicathias textiliosa* (Lam.) *Subninella undulata, Austrocochlea (Chlorodiloma) odontis* (Woods), *Cominella lineolata* (Lam.), *Aplysia tasmanica* (Ten.-Woods), *Notohaliotis ruber* (Leach), *Bembicium nanum* (Lam.), *Lepsithais vinosa, Montfortula rugosa* (Quoy & Gaim.), *Siphonaria tasmanica, S. diemenensis, Patellanax chapmani* (Ten.-Woods) and *Sypharochiton maugeanus*. Some of these species are of particular interest, particularly

*Aplysia tasmanica*. This species was very sporadic in occurrence and was represented by juvenile individuals which were attached by the posterior ends of their foot to *Laurencia* plants. One small plant harboured seven juvenile *Aplysia*. The fissurellid *Montfortula rugosa* was particularly numerous on the reef. In other parts of Tasmania this species is not very common.

The carnivorous gastropod, *Cominella lineolata*, was very numerous in the shallow ponds. *Cominella* always could be found by killing and crushing any other species of animal, whereupon *Cominella* would come out of hiding in the sand to feed on the dead animal. The individuals of *Cominella* live buried in the sand and rapidly make their way over the sand using the smell of the dead animal as a guide. Two varieties of *C. lineolata* were found—that with continuous lines around the shell and that with the lines broken.

The ponds towards the wave exposed end of the reef have the same flora except that *Laurencia botryoides* becomes more scarce. *Macrocystis pyrifera* becomes larger and the plants more numerous but a requirement for this species is a pool of several metres extent. *Lessonia corrugata* Lucas appears in these ponds.

Shallow ponds of less than 10 cms. depth in the *Hormosira-Corallina* belt do not usually support a varied algal flora. Generally speaking the only alga present is *Hormosira* though *Corallina* may or may not also be present. *Patiriella exigua* (Lam.) occurs sporadically throughout these ponds.

Those parts of the reefs which are not submerged support a poor fauna, consisting largely of the semi-cryptic species, *Sypharochiton maugeanus*, *Galeolaria caespitosa* and *Siphonaria diemenensis*.

The seaward part of the reef is exposed to heavy wave action and this factor becomes of greater importance in determining the zonal pattern. A small ridge near the edge of the reef is sufficiently elevated above the general level of the reef to show the zonation in an almost unbroken sequence from the *Chamaesipho* belt down to the Infralittoral fringe. The zonation is *Chamaesipho columna*, *Austromytilus rostratus* (Dunker), *Catophragmus polymerus* Darwin, mixed algal belt, *Lithophyllum hyperellum* Foslie, *Sarcophycus potatorum* (Labill.) Kutz.

This zonation is not necessarily present over all of the exposed edge of the reef. *Catophragmus* is rather patchy in distribution, preferring places where there are rounded fingers of the reef extending out to sea so that surf and broken water passes over the rock. Similarly, the mussels are patchy in distribution and are not found on the most exposed situations. The gullies extending into the reef show a reduction in the number and size of *Sarcophycus* plants in direct proportion to the distance from the edge of the reef and eventually *Sarcophycus* becomes absent and is replaced by *Phyllospora* as the dominant Infralittoral fringe alga. *Macrocystis* often occurs in these gullies. The mixed algal and *Lithophyllum* belts in November were richly populated by *Ulva lactuca*, and a mixed *Scytosiphon* belt was found on the shore above the Infralittoral fringe in places with submaximal exposure.

The barnacle belt at the seaward edge is populated by gastropods, but there are no other species of barnacles present in this belt. *Notoacmea mayi* (May), *Lepsithais vinosa* (Lam.), *Littorina unifasciata*, *L. praetermissa* (May), *Modiolus pulex* and *Patelloida latistrigata* (Angas), are the other species found in the barnacle belt.

The *Austromytilus* belt is populated by *Montfortula rugosa* (Quoy & Gaim.) and by chitons, *Sypharochiton maugeanus* (Iredale & May). A few *Catophragmus* are found at this level but they are all small in size. The anemone, *Actinia tenebrosa* (Farq.) is found in clefts in the mussel belt together with *Galeolaria*. These two species are not found living together. The patelliform gastropods *Patelloida latistrigata*, *Notoacmaea scabrilirata* and *Patellanax chapmani* are found in the *Austromytilus* belt.

The *Catophragmus* belt has the same limpet fauna as that given above for the *Austromytilus* belt but with the fissurellid *Montfortula rugosa* becoming very much more numerous.

One of the striking features of the mixed algal and the *Lithophyllum* belt is that there are no animals, other than small species such as amphipods, living on or inside the weeds. The poverty of fauna extends further down the shore and is to be seen in the *Sarcophycus* belt.

The *Lithophyllum* belt is populated by the limpet *Cellana solida*, a white encrusting *Lithothamnion*, *Laurencia botryoides*, *Ulva*, *Corallina* and a few *Scytosiphon* plants, the large chiton *Plaxiphora albida* (Blainville), a very few *Galeolaria caespitosa*, *Corallina lichenoides*, the *thaid Dicathais textiliosa* (Lam.), and *Patiriella calcar* (Lam.). *Corallina officinalis* may form a turf in some places in the *Lithophyllum* belt.

The *Sarcophycus* belt is the most obvious feature of the intertidal region but it is very poor in fauna and flora. The ascidian *Pyura stolonifera* (Heller) is found attached to the rocks around the holdfasts of the large alga and some clusters formed by *Modiolus pulex*. The latter species often has large numbers of *Kellia australis* (Lam.) around the byssus strands. *Poneroplax albida* is scarce and there are a few *Cellana solida*. *Iridaea sp. ? australasica* occurs between the plants and all of the rock which is not occupied by these species is encrusted by a pink *Lithothamnion sp.*, which is relieved by some black patches of *Isactis*. *Corallina pilulifera* and *Lithophyllum hyperellum* are also found in the *Sarcophycus* belt but are confined to the upper limit of the region. A large button shaped, dark green coloured alga, *Codium spongiosum* Harv., forms a prominent feature of this belt. This *Codium* species is scarce to rare on the shore but it forms such a vivid splash of green in the prevailing pink of *Lithothamnion* that a false impression of its numbers could easily be gained. Small limpets live in the upper part of the *Sarcophycus* belt, these being *Patelloida victoriana* (Singleton), *Patellanax peronii* (Blainville) and *P. squamifera* (Reeve) and the chiton *Poneroplax albida* (Blainville).

The sheltered north eastern side of the reef, although having *Sarcophycus* in the Infralittoral fringe, shows the decreased strength of the wave action in the belt found in the Midlittoral. The

*Hormosira-Corallina* belt extends to the edge of the reef and is replaced by a mixed algal belt with *Laurencia* often predominating and forming a turf. On the sheltered edge of the reef where there is broken water *Catophragmus* is more numerous than on the exposed side.

## 6. NOTES ON NEARBY AREAS

The rocky areas to the south of Trial Harbour are all situated in close proximity to sandy beaches and on account of the very heavy sand scouring experienced in these places there is often a poverty of life on the rocks. The "cut and fill" of sand in these beaches is very great, approximately seven feet of beach removal being noted in December, 1956. The rocks immediately beside the beaches are smooth and polished by the sand and there is no permanent animal or plant life on them with the exception of a few roving forms, such as *Littorina* or *Austrocochlea* living high on the shore, the latter being found in more sheltered places. The mussel *Austromytilus* is apparently least affected by wave action and sand action, being often found in sheets covering the rocks at a level about the lower Midlittoral. Other species which provide competition at this level for the mussels are absent but as the sand scouring diminishes these species put in an appearance, the last to do so being *Sarcophycus*. In some instances the rocky points to the South of Trial Harbour show a zonation of *Littorina, Chamaesipho, Brachyodontes* (perhaps with *Catophragmus*), *Sarcophycus*.

To the north of Trial Harbour, the coast stretches for some miles as cliffs interspaced with small boulder beaches. These, where it is possible to carry out examination, show a typical exposed coast zonation—namely, *Littorina L, Chthamalus, Chamaesipho, Catophragmus, Corallines* (including *Lithophyllum*) and finally *Sarcophycus*. In many places the small mussel is found forming a dense growth on the rocks at the bottom of the *Chamaesipho* belt, especially in places where the surface of the rock is uneven, e.g., at a place known locally as Ladder Hole.

*Cellana solida* and the anemone *Actinia tenebrosa* are both found on the wave sheltered side of boulders. *Galeolaria caespitosa* is also found on the wave sheltered side of rocks but it is most common in places which are sheltered from the full force of the waves where there is broken water. In these situations it forms encrustations not more than 2·5 cms. in thickness.

Other species found very commonly in this part of the coast are *Dicathais baileyana, Poneroplax albida, Lithophyllum hyperellum, Modiolus pulex,* and *Catophragmus polymerus*. The latter is very common in some, but not by any means all, places which suffer wave action plus surf. It is absent from many situations which appear suitable to it.

Ponds in this region support a fauna which is few in species but large in numbers. *Melanerita melanotragus* is one of the most common pond dwelling species. *Cominella lineolata, Austrocochlea obtusa constricta, Austrocochlea odontis* (Wood), *Bembicium nanum* (Lam.), *Sypharochiton maugeanus, Patiriella exigua* are all common together with the orange anemone *Anthothoe* sp. The ponds at highest levels on the shore frequently support a large *Hormosira* population. The edges of the ponds have a few *Cellana* living just out of the water.

One particularly noticeable feature of this part of the coast is the size of the holdfasts of *Sarcophycus,* one particularly large disc being over 30 cms. in width. In most places there are individuals of *Pyura stolonifera* scattered around the holdfasts of this alga.

## 7. DISCUSSION

The Trial Harbour area, although situated on a very exposed part of the coastline, does not exhibit features which can be considered to be typical of strong wave action. The absence of a well developed *Littorina* belt is one such feature. Other features are the absence of a well developed barnacle belt and the development of an *Hormosira-Corallina* association on the reef. However, these features can all be attributed to two local factors, namely the development of a reef extending for some distance off-shore and the absence of cliffs or rocks. This reef greatly reduces the wave action which is encountered at about high water level and this has had the effect of reducing the spray upon which the Littorines depend for their food and moisture. Further, the absence of any cliffs suitable for colonization by the species which habitually live on the upper part of the shore naturally results in the absence of these species.

The reef being at almost the same level from seaward edge to the land is colonized almost entirely by the species which are able to successfully live at that tidal level. On an exposed coast one might expect a mixed *Corallina-Patelloid* barnacle belt as at, for example Eaglehawk Neck (Guiler, 1952). However, the reef at Trial Harbour is of such an extent and apparently has reduced the wave action to such a degree that *Hormosira* is able to survive on the exposed coast, although *Hormosira* is normally a species of more sheltered habitat.

The presence of *Melanerita melanotragus* on the coast near Trial Harbour is of interest. This species was found at the Pieman Heads, some 40 miles further to the north but it is absent from the south coast at South Cape Bay (Guiler, 1954). *Melanerita* occurs very commonly along the north coast (Kershaw, 1956 and Guiler, Serventy & Willis, 1958) and it is also found at Freycinet Peninsula on the East coast. I did not record *Melanerita* at Eaglehawk Neck in 1952 but in February and April, 1957 I found several individuals on the sheltered side of Fossil Island at the Neck. The species can definitely be classified as rare at Eaglehawk. I did not find any specimens at Fortescue Bay, about seven miles further south, in December, 1956. It can be said that Eaglehawk Neck probably represents the southern limit of this species. The southern limit on the west coast must remain a matter for some speculation until examinations can be carried out in this inaccessible area.

One of the features of the south and west coasts is a prominent white *Lithothamnion* which lives characteristically in the Infralittoral fringe around the holdfasts of *Sarcophycus*. I have seen this species in Safety Cove near Port Arthur and Cribb (1954) records the species from Port Arthur. I have seen it at Fortescue Bay but it is not common at Eaglehawk Neck. It does not occur on the north coast or on the northern part of the East coast. It is very common on the south coast at South Cape Bay and also at Trial Harbour. It would appear that this *Lithothamnion* is indicative of cold conditions and does not penetrate far into Australian waters.

The absence of the southern Bull Kelp *Durvillea antarctica* (Cham.) Hariot is worthy of comment. Although much of the drift weed on the shore, particularly to the north of Trial Harbour, is *Durvillea* this material has been carried in the sea for a considerable time since large barnacles, *Lepas australis* Darwin, are found attached to the weed.

## 8. ACKNOWLEDGMENTS

I am grateful to Mr. D. P. Alexander for assistance during the field work and to Mr. T. McMahon for the photographs upon which the plates are based. Mr. R. C. Kershaw and Miss Hope McPherson identified the Molluscs and Miss B. Nielson, Tasmanian Museum identified the tectibranch for me. To these people I extend my thanks.

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Plate I.—The reef looking south. The channel in the foreground is occupied by *Macrocystis*. (Photo T. McMahon).

Plate II.—*Sarcophycus* and the *Lithothamnion* belt at the seaward edge of the reef. (Photo T. McMahon).

Plate III.—*Hormosira* on the surface of the reef.

# A NOTE ON THE ECOLOGY OF THE FAIRY PENGUIN

## *Eudyptula minor novaehollandiae* (Forster 1781) in Southern Tasmania

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### ABSTRACT

The ecology of the fairy penguin *Eudyptula minor novaehollandiae* is being studied in southern Tasmania. Three breeding grounds, one on a rocky shore and two in sandy situations, have been selected for investigation. Twenty-one nesting and moulting holes have been found in the former, while a total of 88 burrows has been pegged at the latter. Regular visits are being made and informatiton is being collected from these nests. Overlapping aluminium flipper rings proved unsatisfactory for banding adult and fledgling penguins and butt-ended stainless steel rings are now being tested. Young chicks are marked by punching the web of the foot. Mated pairs and birds keeping company are being sexed by the method of cloacal examination and the results indicate that the bill depth measurements of adult birds may also be used to distinguish the sexes.

### INTRODUCTION

#### 1. Aims

An extensive programme of banding and observation of the fairy penguin *Eudyptula minor novaehollandiae* is planned to cover a period of several years, with the object of studying, in southern Tasmania:

(*a*) The general breeding biology and moult,
(*b*) The seasonal movements and migratory status,
(*c*) The food cycle relationships,

of this subspecies.

#### 2. Selection of Breeding Areas

To compare the behaviour of populations of this penguin occupying contrasting types of habitats, two separate breeding grounds, one on a rocky and the other on a sandy coast, have been selected as main study areas.

#### A. Breeding Grounds on the Western Shore of the River Derwent

A brief preliminary survey of the rocky coastline of the western shore of the River Derwent, between Blinking Billy Point and Lucas Point, resulted in the discovery of only two areas with a sufficiently high density of penguin nesting holes to warrant the use of the term " rookery ".

One of these breeding grounds lies at the base of the Alum Cliffs at Taronga. However its relative inaccessibility, coupled with the extensive rock-falls to which the overhanging mudstone cliffs are subject, renders this area unsuitable for detailed study.

The second breeding ground is situated at Boronia Bay, Kingston. Along a stretch of rocky shore less than a quarter of a mile long, a total of twenty-one nesting and moulting holes has so far been noted. At the time of their discovery, these contained either eggs, chicks or moulting birds and were therefore definitely occupied by penguins.

They occur as follows:

1. Between or beneath some of the larger dolerite or mudstone boulders.
2. In eroded hollows at the base of the mudstone cliffs.
3. In crevices in the cliff face.
4. At the base of a small low cove.
5. Below a fallen eucalypt.

Some are devoid of any surrounding vegetation, whilst others occur among patches of creeping plants such as *Tetragonia implexicoma* (Moq.) Hook, *Acaena anserinifolia* (Forst.) Druce and *Rhagodia baccata* (Labill.) Moq., or in thickets of the grass *Dactylis glomerata* Linn. and the shrub *Senecio lautus* Sol*.

#### B. Breeding Grounds on Bruni Island

1. *On the " Neck ".*

The breeding ground here extends for several miles along and beyond the narrow strip of sand dunes, which constitutes the tide-bar connecting the two halves of the island and separating the Tasman Sea from the D'Entrecasteaux Channel. The whole area is traversed by a complicated network of tracks, worn by the penguins in their continual pilgrimages to and from their burrows. These occur in large numbers, both on the actual dunes and on the relatively flat stretch of foreshore situated above the tideline on the western side and are dug out of the sand to form tunnels up to six or seven feet long. They usually extend more or less horizontally and may exhibit a pronounced right or left hand bend.

2. *On Cape Queen Elizabeth.*

In order to investigate the interspecific relationship between *Eudyptula minor novaehollandiae* and *Puffinus teniurostris* (Temminck), the mutton bird rookery on Cape Queen Elizabeth, at the north end of Adventure Bay has also been selected as a subsidiary study area.

* The nomenclature given in Curtis (1956) and Black (1929 et seq.) is followed here.

This rookery covers the lower slopes of the hillside on the south-western side of the Cape. The whole area is honeycombed with mutton bird and penguin burrows. As on the "Neck", these may be found under thickets of *Pteridium aequilinum* (Linn.) Kuhn, *Lomandra longifolia* Labill. and *Eleocharis acuta* R.Br., or among patches of *Carpobrotus rossii* Swantes, *Tetragonia implexicoma*, *Acaena anserinifolia* &c. Large numbers also occur in wide eroded areas, which are almost bare of any vegetation.

## METHODS

### 1. Visits to the Study Areas

1958-59 Breeding Season and 1959 Winter Period.

*A. Boronia.*

After the first discovery of occupied nests in this area on January 19th, 1959, regular visits were made twice or thrice weekly and sometimes daily, to the Boronia breeding ground, up till the time of departure of the last pair of fully fledged chicks, between the 7th and 12th of April. On 14 occasions, namely on: January 19th and 31st; February 6th, 9th, 12th, 13th, 15th, 18th, 23rd and 27th; March 6th, and April 5th, 7th and 12th, the bay was reached about an hour before dusk and was left at 10.30-11.00 p.m. A number of daytime trips were also included on the following dates: January 25th and 27th; February 7th, 10th, 14th, and 28th; March 8th, 14th and 22nd; and April 4th.

Throughout the subsequent winter period visits were made to this area at infrequent intervals, mostly during the daytime, as follows: May 23rd; June 20th, August 15th (at night) and 27th, and September 13th.

*B. Bruni Island: Neck.*

The rookery on the Neck at Bruni Island was visited twice in January, principally for the purpose of collecting specimens for an osteological study. One trip, on January 14th, was made in the daytime, whilst the other, on January 21st-22nd, involved a stay overnight. The June long-weekend (June 13th-15th) was also spent on the island, and further observations were made both in the daytime aid at night. Another day trip was made on August 22nd.

1959-60 Breeding Season.

*A. Boronia.*

Since October 4th the Boronia breeding area has been visited regularly, in the daytime, every Sunday. Additional afternoon and evening visits have also been commenced. These are being made daily whenever possible.

*B. Bruni Island: Neck and Cape Queen Elizabeth.*

Irrespective of the weather and with only one exception (September 19th), regular daytime trips have been made to the "Neck" rookery on Bruni Island every Saturday since September 12th. The Cape rookery has also been visited at approximately fortnightly intervals since September 15th. These visits will be continued for the remainder of the season and a stay overnight will be included whenever practicable. In addition several days have been spent camping on the "Neck" rookery in November (16th-21st) whilst a similar trip is planned for December.

### 2. Collection of Data

Most of the data collected so far, in the three study areas, have been obtained by the regular observation of burrows or nesting holes which exhibit some signs of occupation by penguins.

**A. Methods used in Identification of Burrows.**

In the Boronia area a few notes have been proved sufficient to fix the position of the nesting holes. On the Bruni Island rookeries wooden stakes, painted white and bearing serial numbers, have been used to mark the burrows. Labelling has been confined to nests within a small but representative area on each rookery, which, at the time of their discovery, were actually inhabited by penguins. In both cases the total number of marked nests has been increased gradually as more birds have taken possession of empty burrows. Up to date 88 nests have been pegged in the two areas.

**B. Methods used for Banding Adult and Fledgling Penguins.**

1. *Temporary aluminium bands.*

A simple hand-made aluminium flipper band was designed for use as a temporary measure to provide a quick means of marking any birds found in the Boronia study area during the last stages of the 1958-59 breeding season. A strip of 20-guage metal 65 mm. long by 10 mm. wide, bearing a serial number together with the legend:

"WRITE UNIVERSITY
HOBART TASMANIA"

was bent into an overlapping shape and applied, fairly loosely, to the left flipper at the shoulder joint. The overlap was placed dorsally and faced caudally.

Altogether, between February and April, 1959, using these temporary bands a total of 30 adult and eight fledglings was ringed in or near the Boronia area.

These bands proved unsatisfactory for general use for the following reasons:

(*a*) The metal both corroded and abraded so that within six months the numbers were often indistinct and the inscription was usually illegible.

(*b*) The overlapping portion tended to cause serious abrasion of the feathers in the armpit—in most cases actually shearing them off at the base.

(*c*) The anterior and posterior edges tended to cause damage to the flipper itself, particularly at the anterior lower border. Here the excessive width of the band was probably partly to blame.

(*d*) The overlapping shape made it difficult to allow sufficient room for expansion without increasing the bulk enormously. Hence, with the storage of fat at the shoulder joint immediately prior to the moult, the affected flipper tended to become severely swollen.

2. *Permanent Stainless Steel Bands.*

F. C. Kinsky of the Dominion Museum, New Zealand, has designed a more satisfactory type of band, which he has used with considerable success on the Northern Blue Penguin in Wellington Harbour (Kinsky 1959, pp. 12-13). This band consists of a narrow metal strip, two inches long by one-quarter inch wide, and is bent to form a butt ended ring. Initially, Kinsky used the metal duralumin for his bands, but he too encountered the same problem of corrosion. In a personal communication he states that he is now testing out the efficiency of a 20-guage stainless steel. The use of this less pliable material has necessitated an alteration in the design of the ring, in that the lower anterior border now has to be rolled outwards and upwards to form a definite flange to allow for movement of the flipper. A sample band of this new type has been copied for use as a permanent right flipper ring in each of the three study areas. The metal used is a 22-gauge stainless steel, otherwise the specifications are as indicated above. The same inscription is being used as before, together with a serial number prefixed by the letter N ("Neck"), E (Cape Queen Elizabeth) or K (Boronia, Kingston). The latter series is being used to replace the temporary bands of any penguins previously marked in the Kingston area, as well as to ring any new birds encountered there.

### C. Methods used for Marking Eggs and Chicks

Eggs are numbered at each end to denote the order of laying and a leather punch is used to mark the web of the foot of the first hatched chicks.

### D. Data Collected from Burrows

Since the middle of August, on every visit to each of the three study areas, a survey has been made of the burrows previously marked together with those newly labelled. The following information has been collected:—

1. The number of adult birds present and from these:
   - (*a*) The serial number of the flipper band already worn or now applied,
   - (*b*) The condition of the band—especially of the inscription,
   - (*c*) The nature and amount of abrasion caused by the band,
   - (*d*) The weight of each bird,
   - (*e*) The length of its flipper, toe and bill, together with the depth of the latter.
   - (*f*) The general appearance of the bill,
   - (*g*) The condition of the cloaca,
   - (*h*) The state of the plumage and the condition of the feet, &c.,
   - (*i*) The general nature, positon, and relative number of ectoparasites—specimens being collected for identification.
2. The number of eggs present and:
   - (*a*) The appearance of each—their general shape and the amount and nature of soiling, &c.,
   - (*b*) The weight of each,
   - (*c*) The maximum length and breadth of each.
3. The number of chicks present and from these:
   - (*a*) The method previously used or now applied to mark them and its relative efficiency,
   - (*b*) The stage of development of the chick—If in primary down, whether its eyes are open and whether it is yet able to support its own head; if in secondary down, whether any bare patches occur around the eyes, or whether any blue feathers yet appear, and to what extent, &c.,
   - (*c*) The weight of each chick,
   - (*d*) The measurements of its flipper, toe and bill,
   - (*e*) The nature, position and relative number of ectoparasites.
4. The condition of the nest:
   - (*a*) The amount and position of excreta outside and inside,
   - (*b*) The condition of the 'tunnel" and of the nesting chamber itself—whether damp or dry, &c.,
   - (*c*) The nature and amount of nest material present.

### E. Equipment

Owing to the length of many of the sand-dug burrows and to the inaccessibility of most of the nesting holes among boulders, some device for extracting the birds was found essential. Two different tools have been designed for this purpose. One of these consists of a 4-ft. length of hollow flexible tubing through the centre of which a double strand of brown plastic-covered wire is threaded so that it leaves an adjustable loop at one end. This can then be slipped over the head of any penguin facing the entrance of the nest. The second tool consists simply of a 4-ft. metal rod provided with a handle at one end and a hook at the other, which can be looped round the leg of any bird facing sideways or presenting its tail to the viewer.

For making the measurements listed above, a pair of 150 mm. calipers, provided with a vernier scale measuring to 0·1 mm. and a set of balance-type scales weighing up to 10 lbs in ¼ ozs. are used. Adults and older chicks must be wrapped up in a cloth bag before placing on the pan.

## DISCUSSION

Observations have not yet extended over a sufficient period for any definite conclusions to be drawn, but some evidence is available to indicate a possible method of sexing adult birds which are not breeding.

### 1. Previous Work on Sexing

L. E. Richdale, who, in New Zealand, has carried out over eighteen years of research work on the allied genus *Megadyptes antipodes* (Hombron and Jacquinot) writes (1951, p. 107): "The only certain way of sexing the Yellow-Eyed Penguin other than by dissection, is to examine the vent of both birds of a mated pair in the span of egg deposition*.

* This is also the method adopted by Serventy (1956, p. 213) for sexing mutton birds in the field.

Both in this (op. cit. p. 109) and in his later work (1957, pp. 2-3) he claims that, by this means and with the aid of eleven further points which he uses as tentative guides, he has been able accurately to sex every yellow-eyed penguin living in his study area. In his earlier paper on the genus *Eudyptula*, Richdale (1940, pp. 180-217) does not specifically mention the problem of sexing although he refers to several of his banded birds as males or females.

P. J. O'Brien (1940, pp. 311-312) claims to be able to distinguish the sexes in the white flippered penguin *Eudyptula albosignata* Finsch chiefly by comparing the shape of the bills and the size of the white patch at the base of the tails in the adult birds. He states that in the male the beak tends to be heavier and more square at the tip, while in the female it is " usually more slender and is never as hooked as in the male ". He gives no measurements, but includes an illustration of the two forms.

F. M. Littler (1910, p. 210) likewise claims to be able to separate the sexes in *Eudyptula minor* by comparing the appearance and behaviour of the adult birds, but he gives little definite supporting evidence.

E. B. Nicholls (1918, p. 127), in his discussion of the same sub-species at Phillip Island, Victoria, also mentions a superficial difference between the sexes. He includes a table showing the culmen measurements of seven male and nine female skin specimens. In this, the bill depth measurement is certainly consistently larger in the males, but his evidence seems inadequate to justify any definite assumptions.

In a later paper, W. B. Alexander, in conjunction with Nicholls (Alexander and Nicholls 1918, pp. 54-55) tabulates, together with the above data, the culmen measurements of a further 17 skin specimens, including 12 from Victoria, 2 from New South Wales, 2 from Western Australia and 1 from South Australia. Here a considerable overlap is apparent between the sexes, but the same criticism still applies, especially as Tasmanian forms are unrepresented.

## 2. Results Obtained in the Present Study

Observations made on the appearance and behaviour of three juvenile penguins reared in captivity, of which two subsequently died and on dissection proved to be males, have to some extent confirmed the claims made by Littler and Nicholls. The bills of these two birds were definitely stouter and more powerful, while their heads were both larger and more square in outline than that of the sole survivor. The latter is assumed to be a female, partly because of the interest it showed in the displays* made by these two males, and partly because of its actual response to similar displays made by another older partner subsequently obtained for it. From the time of their capture as three to four-week-old chicks, the two males tended to be more aggressive than the assumed female and even after several months of constant handling were often quite vicious in their behaviour.

Since dissection is out of the question in an extended ecological study, an attempt is being made to determine the sex of as many penguins as possible, especially of mated pairs, using the method of cloacal examination. Forty-one out of the 153 adult birds, banded in the three study areas between September 12th and November 30th have been positively identified as females. In each case the cloaca has been greatly distended and inflamed during the week or so before and after egg-laying. No comparable changes have been observed in the vents of the partners of these birds. That these partners are mated pairs, has been deduced from, in 22 instances, the observation of the same two birds taking regular turns brooding the same eggs or chicks. In a further 15 cases the relationship between the pairs is more uncertain since they have only been observed keeping company. Twelve individuals have changed partners, one of them twice and in five of the nests involved in these exchanges, clutches of eggs have subsequently appeared.

In an attempt to find a method of differentiating the sexes during the remaining stages of the annual cycle, a correlation has been sought between the sex of each bird and its measurements. For this purpose three tables have been compiled (see appendix). Tables 2 and 3 give the flipper, toe and bill (length and depth) measurements of the series of 15 couples keeping company and of the 22 mated pairs incubating eggs and guarding chicks which have been sexed as indicated above. Table 1 lists the same data for the collection of 20 adult penguins, which were dissected in the course of an osteological study. In this case a number of additional measurements, namely the total, tail and tarsal lengths, together with the bill widths, are also included. These can only satisfactorily be obtained from dead specimens. In the estimation of the flipper, toe and bill length measurements, the procedure outlined by Richdale (1940, p. 200) has been followed throughout, while in the compiling of the additional data for Table 1, the standardized methods listed by Gurr (1947, pp. 59-60) have been used. Gurr's method of estimating the depth of the bill at its base was, however, found difficult to apply later out in the field. Hence the procedure outlined by Nicholls (1918, p. 119) for measuring the bill depth at the gonys, has been adopted for use on live penguins. This means that with regard to this particular measurement, the figures contained in Table 1 cannot strictly be compared with those of Tables 2 and 3. Furthermore, since the measurements for Table 1 were made using a ruler, the figures here have been corrected to the nearest whole number. On the other hand, all subsequent measurements have been made with the aid of a vernier scale, hence a greater degree of accuracy has been attained. In the case of the bill length and depth measurements listed in Table 3, estimations have been made for each bird on at least two and usually on three or four separate occasions. The figures included under the appropriate columns in this Table

* These took the form of the half and full trumpet displays described and figured for this sub-species by Warham (1958, pp. 611-612).

therefore represent the mean of two or more different readings. This also applies to several of the bill measurements listed in Table 2. The toe and flipper measurements of live birds have each been estimated only once and have been corrected to the nearest 0·5 mm.

Although the data contained in the above tables are insufficient for any definite conclusions to be reached, the following points may be noted:—

(*a*) In each table the bill depth measurements show a smaller degree of overlap between the two sexes than any of the other measurements.

(*b*) With only one exception, where a 0·1 mm. overlap occurs, in each of the pairs of birds included in Tables 2 and 3, the bill depth measurement of the female is less than that of the male. This cannot be stated of any of the other data.

(*c*) If changes of partners are as common, in the pre-egg period, as Table 2 appears to indicate, then the problem of sexing will clearly be simplified.

(*d*) A study of the bills of the 20 specimens included in Table 1 and of the 153 specimens examined in the field has not revealed any clear-cut sex difference with regard to the degree of curvature of the upper mandible, comparable with that described by O'Brien.

### 3. Future Work.

The collecting and assessing of data along the lines outlined above will be continued for the remainder of the present egg-laying season. When mated pairs or single birds are encountered subsequently, so that sex determination by the cloacal method is impossible, a provisional attempt at sexing will be made, to await confirmation at a later date. In the case of mated pairs, this will be based on a comparison of their bill depth measurements, in the case of single birds, the absolute bill depth measurement will be used as a guide, on the assumption that this lies within the range 11·4-13·2 mm. in females and within the range 13·0-15·6 mm. in males. In both instances the general appearance and behaviour of the birds concerned will be noted and recorded.

The extent to which the bill may continue to grow in adult penguins also requires investigation.

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## TABLE 1.

Table of measurements of a series of 20 adult specimens of *Eudyptula Minor Novaehollandiae*, dissected in the course of an Osteological Study.

MALES

| Locality of Collection | Date of Collection | Specimen No. | Bill Length in mm. | Bill Depth in mm. | Bill Width in mm. | Middle Toe and Claw in mm. | Middle Claw in mm. | Flipper Length in mm. | Total Legnth in mm. | Tail in mm. | Tarsus Front in mm. | Tarsus Diagonal in mm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marion Bay .. .. | 11.1.59 | 2 | 38 | 15 | 12 | 49 | 16 | 117 | 385 | 27 | 29 | 35 |
| Bruni Island "Neck" .. | 15.1.59 | 5 | 41 | 16 | 13 | 52 | 16 | 122 | 402 | 29 | 30 | 35 |
| " " | " | 7 | 40 | 16 | 14 | 50 | 15 | 122 | 391 | 30 | 29 | 35 |
| " " | " | 8 | 42 | 17 | 15 | 54 | 17 | 122 | 394 | 32 | 29 | 35 |
| " " | 21.1.59 | 10 | 40 | 17 | 14 | 52 | 18 | 121 | 408 | 28 | 30 | 36 |
| " " | " | 12 | 38 | 15 | 11 | 50 | 15 | 120 | 408 | 29 | 29 | 35 |
| " " | " | 17 | 38 | 15 | 12 | 52 | 16 | 117 | 389 | 30 | 30 | 38 |
| " " | " | 18 | 40 | 16 | 14 | 54 | 18 | 121 | 390 | .. | .. | .. |
| Seven Mile Beach" .. .. | 17.3.59 | 19 | 38 | 15 | 13 | 50 | 15 | 119 | .. | .. | 28 | 34 |
| Fulham Island .. .. | 26.3.59 | 21 | 41 | 15 | 13 | 49 | 13 | 121 | 392 | .. | 28 | 34 |
| " " | " | 22 | 40 | 15 | 14 | 49 | 15 | 125 | 408 | .. | 28 | 33 |
| " " | " | 23 | 37 | 15 | 13 | 48 | 13 | 118 | 418 | .. | 27 | 33 |
| Maximum .. .. | | | 42 | 17 | 15 | 54 | 18 | 125 | 418 | 30 | 30 | 38 |
| Minimum .. .. | | | 37 | 15 | 11 | 48 | 13 | 117 | 385 | 27 | 27 | 33 |
| Average .. .. | | | 39 | 16 | 13 | 51 | 16 | 120 | 399 | 29 | 29 | 35 |

## TABLE 1.

Table of measurements of a series of 20 adult specimens of *Eudyptula Minor Novaehollandiae*, dissected in the course of an Osteological Study.

FEMALES

| Locality of Collection | Date of Collection | Specimen No. | Bill Length in mm. | Bill Depth in mm. | Bill Width in mm. | Middle Toe and Claw in mm. | Middle Claw in mm. | Flipper Length in mm. | Total Length in mm. | Tail in mm. | Tarsus Front in mm. | Tarsus Diagonal in mm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bruni Island "Neck" .. | 15.1.59 | 6 | 38 | 14 | 13 | 50 | 13 | 120 | 380 | .. | 28 | 33 |
| ,, ,, | ,, | 9 | 38 | 13 | 13 | 47 | 14 | 115 | 375 | .. | 27 | 34 |
| ,, ,, | 21.1.59 | 11 | 40 | 14 | 12 | 47 | 14 | 112 | 406 | 30 | 28 | 33 |
| ,, ,, | ,, | 13 | 37 | 15 | 14 | 48 | 15 | 117 | 399 | 29 | 32 | 36 |
| ,, ,, | ,, | 14 | 35 | .. | 11 | 50 | 15 | 120 | 385 | 30 | 30 | 35 |
| ,, ,, | ,, | 15 | 39 | 13 | 12 | 50 | 15 | 119 | 379 | 26 | 30 | 37 |
| ,, ,, | ,, | 16 | 40 | 14 | 12 | 48 | 14 | 118 | 376 | 28 | 29 | 32 |
| Fulham Island .. .. | 26.3.59 | 20 | 35 | 13 | 11 | 45 | 14 | 118 | 387 | .. | 29 | 34 |
| Maximum .. .. | | | 40 | 15 | 14 | 50 | 15 | 120 | 406 | 30 | 32 | 37 |
| Minimum .. .. | | | 35 | 13 | 11 | 45 | 13 | 112 | 375 | 26 | 27 | 32 |
| Average .. .. | | | 38 | 14 | 12 | 48 | 14 | 117 | 386 | 29 | 29 | 34 |

## TABLE 2.

Table of measurements of 15 pairs of *Eudyptula minor novaehollandiae* observed at least once "keeping company" and sexed by the method of cloacal examination during the 1959 egg-laying and incubation season.

| MALES | | | | | | | | FEMALES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. | Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. |
| Bruni Is.: "Neck" | Oct. 3 .. .. | 1 | N7 | 38.5 | 14.5 | 48.0 | 119.5 | Bruni Is.: "Neck" | Oct. 3 .. .. | 1 | *N6 | 41.0 | 13.0 | 47.0 | 120.0 |
| ,, | Sept. 12:26 .. | 1 | *N1 | 37.9 | 15.4 | 52.0 | 124.0 | ,, | Sept. 12 .. | 1 | N6 | | | | |
| | Oct. 17:24 .. | 1 | | | | | | | | | | | | | |
| | Nov. 7:14:16:20: 21 .. | 1 | N1 | | | | | ,, | Nov. 14:16 .. | 1 | *N59 | 37.3 | 12.6 | 47.0 | 115.5 |
| | Nov. 28 .. | 41 | N102 | 38.2 | 15.0 | 49.0 | 119.5 | ,, | Nov. 28 .. | 41 | N59 | | | | |
| ,, | Oct. 10 .. | 3 | N21 | 37.5 | 13.0 | 49.5 | 119.0 | ,, | Oct. 10 .. | 3 | N22 | 38.0 | 11.5 | 44.0 | 114.5 |
| ,, | Oct. 3 .. .. | 12 | *N11 | 36.5 | 14.5 | 48.5 | 119.0 | ,, | Oct. 3 .. .. | 12 | *N10 | 34.5 | 11.6 | 44.0 | 115.5 |
| | Nov. 14:16:17:28 | 29 | | | | | | | Nov. 7:16:17:21 | 30 | | | | | |
| ,, | Oct. 17 .. | 18 | *N32 | 36.9 | 13.9 | 46.0 | 118.5 | ,, | Sept. 26 .. | 5 | | | | | |
| | Nov. 7:28 .. | 18 | | | | | | | Oct. 17 .. | 18 | *N2 | 36.6 | 12.0 | 46.0 | 117.0 |
| | | | | | | | | | Nov. 7:14:21 .. | 21 | | | | | |
| ,, | Nov. 17 .. | 19 | N64 | 36.7 | 13.0 | 48.5 | 113.5 | ,, | Nov. 7 .. | 23 | | | | | |
| ,, | Oct. 31 .. | 20 | | | | | | | Nov. 17 .. | 19 | N48 | 38.3 | 13.1 | 48.0 | 118.5 |
| | Nov. 14:16:17:20 | 20 | *N47 | 38.6 | 13.8 | 50.0 | 123.0 | ,, | Nov. 14 .. | 20 | N60 | 34.0 | 12.6 | .. | .. |
| ,, | Nov. 7:16:17:20 | 25 | *N50 | 37.1 | 13.3 | 48.0 | 116.5 | ,, | Nov. 7:14:20 .. | 26 | *N51 | 35.1 | 11.6 | 49.0 | 114.0 |
| | Nov. 28 .. | 26 | | | | | | | Nov. 28 .. | 26 | | | | | |
| ,, | Nov. 19:28 .. | 46 | N80 | 40.8 | 13.9 | 47.5 | 116.0 | ,, | Nov. 19:28 .. | 46 | N87 | 37.0 | 13.1 | 49.0 | 120.5 |
| Bruni Is.: Cape Queen Elizabeth | Oct. 22 .. | Q5 | E16 | 37.9 | 14.1 | 48.0 | 123.5 | Bruni Is.: Cape Queen Elizabeth | Oct. 22 .. | Q5 | E15 | 36.2 | 12.8 | 46.5 | 118.0 |
| | | | | | | | | | Sept. 15 .. | Q4 | | | | | |
| | Oct. 22 .. | Q34 | E14 | 39.6 | 14.0 | 50.5 | 125.0 | | Oct. 22 .. | Q34 | E13 | 38.3 | 12.3 | 46.0 | 117.0 |
| Kingston: Boronia | Oct. 10 .. | B1 | | | | | | Kingston: Boronia | Nov. 11:13 .. | B5 | | | | | |
| | Nov. 11 .. | B5 | K7 | 39.3 | 13.6 | 45.5 | 120.5 | | | | | | | | |
| | Nov. 26:29 .. | B6 | | | | | | | | | | | | | |
| ,, | Nov. 1:6:8 .. | B6 | *K2 | 39.3 | 14.1 | 49.0 | 119.0 | | | | *K6 | 35.8 | 11.5 | 48.0 | 118.0 |
| | Nov. 22:23 .. | B6 | | | | | | ,, | Nov. 22 .. | B6 | | | | | |
| | Nov. 24:26:27:30 | B3 | | | | | | | Nov. 24:26:30 . | B3 | | | | | |
| | Maximum .. .. | | | 40.8 | 15.4 | 52.0 | 125.0 | | Maximum .. .. | | | 41.0 | 13.1 | 49.0 | 120.5 |
| | Minimum .. .. | | | 36.5 | 13.0 | 45.5 | 113.5 | | Minimum .. .. | | | 34.0 | 11.5 | 44.0 | 114.0 |
| | Average .. .. | | | 38.3 | 14.0 | 48.5 | 120.0 | | Average .. .. | | | 36.8 | 12.3 | 47.0 | 117.0 |

* In these cases changes of partners have occurred. See also Table 3.

## TABLE 3.

Table of measurements of 22 mated pairs of *Eudyptula minor novaehollandiae* sexed by the method of cloacal examination during the 1959 egg-laying and incubation season.

| MALES | | | | | | | | FEMALES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. | Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. |
| Bruni Is.: "Neck" | Sept. 12:26 .. | 1 | | | | | | Bruni Is.: "Neck" | | | | | | | |
| | Oct. 17:24 .. | 1 | N1 | 37.9 | 15.4 | 52.0 | 124.0 | | Oct. 24:31 .. | 1 | N34 | 39.6 | 12.7 | 49.0 | 119.5 |
| | Nov. 7:14:16:20 | 1 | | | | | | | Nov. 7:16:17:20 | 1 | | | | | |
| | 21 .. | 1 | | | | | | | 21:29 .. | 1 | | | | | |
| | Sept. 12 .. | 2 | | | | | | | Sept. 12 .. | 2 | | | | | |
| ,, | Oct. 3:17:24:31 | 11 | N8 | 38.8 | 14.6 | 46.0 | 120.0 | ,, | Oct. 3:24 .. | 11 | N9 | 36.3 | 12.0 | 48.0 | 118.0 |
| | Nov. 7:16:17:20: | 11 | | | | | | | Nov. 14:16:17 . | 11 | | | | | |
| | 21:28 .. | 11 | | | | | | | | | | | | | |
| ,, | Sept. 12:29 .. | 4 | | | | | | ,, | | | | | | | |
| | Oct. 10:17:31 .. | 4 | N5 | 37.9 | 14.8 | 49.0 | 124.0 | | Oct. 3:24 .. | 4 | N17 | 36.5 | 11.7 | 49.0 | 124.0 |
| | Nov. 7:16:17:20 | 4 | | | | | | | Nov. 16:17:20 . | 4 | | | | | |
| | Oct. 3:17:31 .. | 9 | | | | | | | Oct. 3:10:24 .. | 9 | | | | | |
| ,, | Nov. 16:17:20:21 | 9 | N18 | 39.8 | 14.6 | 50.0 | 124.0 | ,, | Nov. 7:14:16:17: | 9 | N19 | 36.9 | 12.1 | 46.5 | 118.0 |
| | | | | | | | | | 20:28 .. | 9 | | | | | |
| | Oct. 10:31 .. | 10 | | | | | | | Oct. 3:17 .. | 10 | | | | | |
| ,, | Nov. 7:16:17:21: | 10 | N24 | 36.8 | 14.2 | 48.5 | 118.5 | ,, | Nov. 14:16:17 . | 10 | N20 | 36.8 | 12.4 | 45.0 | 121.0 |
| | 28 .. | 10 | | | | | | | | | | | | | |
| | Oct. 3 .. .. | 12 | | | | | | ,, | | | | | | | |
| ,, | Nov. 14:16:17:28 | 29 | N11 | 36.5 | 14.5 | 48.5 | 119.0 | | Nov. 7:16:17:20: | 29 | N53 | 36.9 | 13.1 | 46.5 | 118.5 |
| | | | | | | | | | 21 .. | 29 | | | | | |
| | Oct. 3:24 .. | 13 | | | | | | | Oct. 3:17:24:31 | 13 | | | | | |
| ,, | Nov. 7:16:17:21: | 13 | N13 | 38.9 | 13.3 | 49.5 | 122.0 | ,, | Nov. 14:16 .. | 13 | N12 | 38.0 | 12.0 | 46.0 | 118.5 |
| | 28 .. | 13 | | | | | | | | | | | | | |
| | Oct. 10 .. | 14 | | | | | | | Oct. 10 .. | 14 | | | | | |
| ,, | Nov. 7:14:16:19: | 24 | N26 | 36.3 | 14.1 | 50.0 | 119.5 | ,, | Nov. 7:16:17:19: | 24 | N25 | 37.8 | 12.6 | 46.0 | 113.0 |
| | 28 .. | 24 | | | | | | | 20:21 .. | 24 | | | | | |
| | | | | | | | | ,, | Sept. 26 .. | 5 | | | | | |
| ,, | Oct. 17 .. | 14 | | | | | | | Oct. 17 .. | 18 | | | | | |
| | Oct. 24 .. | 21 | N30 | 39.2 | 15.1 | 50.5 | 124.0 | | Oct. 24 .. | 18 | N2 | 36.6 | 12.0 | 46.0 | 117.0 |
| | Nov. 7:16:17:28 | 21 | | | | | | | Nov. 7:14:21 .. | 21 | | | | | |
| | Oct. 17 .. | 18 | N32 | 36.9 | 13.9 | 46.0 | 118.5 | ,, | Oct. 10:24:31 .. | 14 | N27 | 35.4 | 12.9 | 49.0 | 123.0 |
| ,, | Nov. 7:28 .. | 18 | | | | | | | Nov. 21:28 .. | 18 | | | | | |
| ,, | Oct.24 .. | 20 | | | | | | ,, | Oct. 24 .. | 20 | | | | | |
| | Nov. 16:17:19: | 33 | N35 | 40.8 | 14.1 | 49.5 | 123.5 | | Nov. 17 .. | 33 | N36 | 36.1 | 11.9 | 49.5 | 116.0 |
| | 20:21:28 . | 33 | | | | | | | Nov. 19 .. | 39 | | | | | |
| | Oct. 31 .. | 20 | | | | | | ,, | Oct.31 .. | 20 | | | | | |
| ,, | Nov. 14:16:17: | 20 | N47 | 38.6 | 13.8 | 50.0 | 123.0 | | Nov. 16:17:20: | 20 | N46 | 36.7 | 12.7 | 43.0 | 114.5 |
| | 20 .. | 20 | | | | | | | 21:28 .. | 20 | | | | | |
| ,, | Nov. 7:16:17:20 | 25 | | | | | | ,, | Nov. 7:14:16:17: | 25 | | | | | |
| | | | N50 | 37.1 | 13.3 | 48.0 | 116.5 | | 20 .. | 25 | N49 | 37.0 | 12.5 | 48.0 | 112.0 |
| | Nov. 28 .. | 26 | | | | | | | | | | | | | |
| ,, | Nov. 17:28 .. | 26 | N63 | 40.7 | 14.6 | 47.0 | 118.0 | ,, | Nov. 7:14:20:28 | 26 | N51 | 35.1 | 11.6 | 49.0 | 114.0 |
| | | | | | | | | ,, | Oct. 3 .. .. | 12 | | | | | |
| ,, | Nov. 16:17:20:28 | 30 | N61 | 39.9 | 15.1 | 50.0 | 119.5 | | Nov. 7:16:17:21 | 30 | N10 | 34.5 | 11.6 | 44.0 | 115.5 |
| ,, | Nov. 16:17:20: | 34 | | | | | | | | | | | | | |
| | 21:28 .. | 34 | N62 | 40.8 | 14.8 | 49.0 | 124.0 | ,, | Nov. 19:20:21 . | 34 | N72 | 37.0 | 12.5 | 49.0 | 124.0 |
| | Nov. 17:20:28 . | 36 | N67 | 37.7 | 13.1 | 49.5 | 118.5 | ,, | Nov. 19:21 .. | 36 | N84 | 37.6 | 12.7 | 45.5 | 117.0 |
| ,, | Nov. 17:19:20: | 38 | | | | | | | | | | | | | |
| ,, | 21:28 .. | 38 | N71 | 38.6 | 13.5 | 48.6 | 119.5 | ,, | Nov. 17:28 .. | 38 | N70 | 36.5 | 12.6 | 50.0 | 114.5 |
| | Nov. 19.20:28 . | 39 | N74 | 42.5 | 15.2 | 50.0 | 118.5 | ,, | Nov. 19.21 .. | 39 | N73 | 35.8 | 11.4 | 49.0 | 117.5 |
| ,, | Nov. 19:28 .. | 45 | N79 | 39.7 | 13.8 | 50.0 | 117.5 | ,, | Nov. 20:21 .. | 45 | N92 | 35.9 | 11.7 | 47.0 | 112.0 |
| ,, | | | | | | | | | | | | | | | |
| Kingston: Boronia | Oct. 18 .. | B3 | | | | | | Kingston: Boronia | Oct. 18:25 .. | B3 | | | | | |
| | Nov. 1:6:8:24: | B3 | | | | | | | | | | | | | |
| | 26:27:30 . | B3 | K2 | 39.3 | 14.1 | 49.0 | 119.0 | | Nov. 6.. .. | B3 | K1 | 35.9 | 12.9 | 47.5 | 120.0 |
| | Nov. 22:23 .. | B6 | | | | | | | | | | | | | |
| ,, | Nov. 6:11:18:23: | B4 | | | | | | ,, | Nov. 6:8:12:13: | | | | | | |
| | 25:27:30 . | B4 | K5 | 40.7 | 15.4 | 48.5 | 122.5 | | 15:22:24:26:29 | B4 | K4 | 35.8 | 11.8 | 48.0 | 121.5 |
| | Maximum .. .. | | | 42.5 | 15.4 | 52.0 | 124.0 | | Maximum .. .. | | | 39.6 | 13.1 | 50.0 | 124.0 |
| | Minimum .. .. | | | 36.3 | 13.1 | 46.0 | 116.5 | | Minimum .. .. | | | 34.5 | 11.4 | 43.0 | 112.0 |
| | Average .. .. | | | 38.9 | 14.3 | 49.0 | 120.5 | | Average .. .. | | | 36.6 | 12.2 | 47.0 | 118.0 |

## TABLE 4.

Additional Data Obtained from Six Late Laying Pairs of *Eudyptula minor novaehollandiae*, sexed by the method of cloacal examination during the month of December.

| MALES | | | | | | | | FEMALES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. | Locality | Dates when observed | Burrow No. | Specimen No. | Bill Length in mm. | Bill Depth (at gonys) in mm. | Middle Toe and Claw in mm. | Flipper in mm. |
| Bruni Is.: "Neck" | Oct. 10:24 .. | 8 | * | | | | | Bruni Is.: "Neck" | Oct. 3:17:31 .. | 8 | * | | | | |
| " | Nov. 7:14 .. | 28 | N23 | 43.2 | 15.6 | 54.0 | 124.0 | " | Nov. 7 .. | 28 | N16 | 34.4 | 12.1 | .. | 118.0 |
| | | | | | | | | " | Dec. 5 .. | 28 | | | | | |
| " | Oct. 17:24 .. | 17 | | | | | | " | Oct. 31 .. | 17 | | | | | |
| | Nov. 7:16:17 .. | 17 | N31 | 37.7 | 14.7 | 51.0 | 118.0 | | Nov. 14:16:17 | 17 | N45 | 35.9 | 13.2 | 47.0 | 121.5 |
| | Nov. 21:28 .. | 17 | | | | | | | | | | | | | |
| | Dec. 19:25 .. | 17 | | | | | | | Dec. 5:25:28:29 | 17 | | | | | |
| " | Oct. 17:24 .. | 19 | * | | | | | " | Oct. 24 .. | 19 | | | | | |
| | Nov. 14:16:17:20 | 32 | N33 | 37.8 | 13.3 | 49.0 | 121.5 | | Nov. 14:16:20 | 32 | N40 | 36.8 | 12.8 | 47.5 | 112.0 |
| | | | | | | | | | Dec. 5:28 .. | 32 | | | | | |
| " | Nov. 19:21 .. | 41 | N75 | 36.0 | 13.2 | 47.5 | 118.5 | " | Nov. 20 .. | 41 | N93 | 38.8 | 12.6 | 46.5 | 116.0 |
| | Dec. 5:28:29 | 41 | | | | | | | Dec. 5:12:19:25 | 41 | | | | | |
| " | Dec. 5 .. | 53 | *N113 | 37.8 | 14.6 | .. | .. | " | Dec. 5:12 .. | 53 | *N111 | 37.1 | 12.9 | .. | .. |
| | | | | | | | | " | Oct. 18:25 .. | B3 | | | | | |
| | | | | | | | | | Nov. 6 .. | B3 | | | | | |
| " | Dec. 4:6:11 .. | L1 | K14 | 38.9 | 13.8 | 44.0 | 117.5 | | Dec. 4:8 .. | L1 | *K1 | 35.9 | 12.9 | 47.5 | 120.0 |
| | Dec. 13-18:31 .. | L1 | | | | | | | | | | | | | |
| | Maximum .. .. | | | 43.2 | 15.6 | 54.0 | 124.0 | | Maximum .. .. | | | 38.8 | 13.2 | 47.5 | 121.5 |
| | Minimum .. .. | | | 36.0 | 13.2 | 44.0 | 117.5 | | Minimum .. .. | | | 34.4 | 12.6 | 46.5 | 112.0 |
| | Average .. .. | | | 38.6 | 14.2 | 49.0 | 120.0 | | Average .. .. | | | 36.5 | 12.7 | 47.0 | 117.5 |

*These birds subsequently disappeared or deserted their nests.

## ADDITIONAL DATA.

Further data obtained between December 5th and March 5th has confirmed the relationship between 15 of the 22 pairs assumed to be mated and listed in Table 3. Three of the remaining seven pairs (N1 and N34, N49 and N50, K1 and K2) deserted their eggs in November and subsequently changed partners, while four apparently lost their mates. N36 was found dead( and her sex was confirmed by dissection) on November 19th. Several bands, including that of N18, were found opened and discarded early in December. N17, N67and N84 disappeared at the same time. During the following weeks further desertions and disappearances occurred in one particular section of the Neck study area. Burrows 18, 20, 21, 24, 38, 39 and 45 were among the nests involved.

An additional six pairs of birds were sexed in December, in four cases (N16 and N23, N45 and N31, N93 and N75, K1 and K14) upon the laying of a second clutch of eggs. The data obtained from these late layers is tabulated below (see Table 4). The bill depth measurement of each of the six females is again considerably less than that of her partner.

# TWO NATIVE SONG-STYLES RECORDED IN TASMANIA

## (with six musical examples)

By

Alice M. Moyle

Since the war, developments in portable recording equipment have greatly assisted anthropologists, musicologists and other deeply concerned with the need to collect and preserve recordings of indigenous singing before it has been forgotten.

In Australia and adjacent islands, commencing with the Australian-American expedition to Arnhem Land in 1948, increasing numbers of field recordings have been made.

Musicological interest has been aroused and as a result several early collections of wax cylinder recordings have been recovered from oblivion.

In 1955, part of Spencer and Gillen's first recordings of central Australian aboriginal music, made in 1901, were located in Adelaide. In 1957, the remainder of this collection and a later set made in the Northern Territory were successfully re-recorded on tape in the National Museum of Victoria[1].

Other collections, made some thirty years ago in Australia, Ontong Java and New Ireland, were dubbed on tape in the Archives of the University of Sydney, last year.

Elsewhere in this volume Mr. M. J. Longman has dealt with the origin and re-recording of the wax cylinder collection in the Tasmanian Museum. Though they are not as numerous as Baldwin Spencer's recordings, they nevertheless have the distinction of being a year or two older. And, because the chances of hearing any other Tasmanian singing are very remote, the recordings are of considerable historical value.

As one might expect, the sound-quality of early Edison phonograph recordings compares unfavourably with the more faithful results obtained by electrical recording on tape. The loss of high and low frequencies and the pronounced noise level in the playback leave much to be desired.

But even from cylinders which have badly deteriorated, with voice signals close to inaudability (and the Tasmanian samples are well above this standard) it is still possible to extract some musicological information.

One has no difficulty in distinguishing two markedly different styles of singing in each of the two groups of cylinder recordings made by Mrs. Fanny Cochrane Smith in 1899 and 1903.

The first, which will be called here the "corroboree" style is in fairly regular triplet, or triole, rhythm and is syllabic. That is to say, as far as the ear can judge, each tone is allotted one syllable of the song-text (Examples 1, 2 and 3).

Th second style, the "Birds and Flowers" song, which for brevity will be called the "legato" style, is not syllabic, but melismatic. It is slower in tempo, has long phrases, non-periodic rhythm and considerable ornamentation. It is in marked contrast to the "corroboree" style of singing and the tones of longest duration are produced in a bleating or pulsating manner (Example 5; indicated by dots . . . .).

Compared with the Vedda songs of Ceylon, often quoted as being among the most primitive musical atterances, these Tasmanian songs show considerably more musical organisation. In each there is a compass of an octave and seven or eight appreciably different tones. The melodies proceed upwards as well as downwards and the phrases follow in recognisable sequence. Neither style has less than four different note-values or durational signs.

In the "legato" style the phrases are balanced above and below a tonal centre, as in a plagal mode. This suggests a more musically advanced style than the "corroboree" song, which accumulates phrases without producing melodic symmetry.

The "corroboree" song has been recorded in three different versions.

A comparison of the first two versions (on cylinders No. 1 recorded in 1899, Example 1 and No. 4, recorded by Horace Watson in 1903, Example 2) shows melodic differences which might be regarded merely as "improvisational". In both cases Mrs. Fanny Smith is singing the same song-type and, allowing for the four-year lapse in time, her musical memory is good. It will be noticed that the ascending phrase in Example 1, bars 10-13 and Example 2, bars 14-18, is almost identical.

Apparently Horace Watson was able to record for a longer duration on his machine. In his recordings Fanny Smith sings more of each song than in 1899, when she performed before members of the Royal Society of Tasmania.

The third and longest version of the "corroboree" song, not transcribed here, is recorded on cylinder No. 6. A duplicate of this, more clearly audible, is to be heard on the Australian Broadcasting Commission's disc-dubbing (16-inch) in the Federal Historical Library, Sydney.

There is no reason to doubt that the "corroboree" style was widely known in Tasmania about 100 years ago. Evidence for this is to be found in a transcription arranged for voice and piano accompaniment by Mrs. Logan. A copy of the voice part made from the original manuscript in the Tasmanian Museum appears in Example 3.

(1) Sir Baldwin Spencer's recordings of Australian Aboriginal Music (*Mem. Nat. Mus. Vict.* No. 24), 1959.

Mr. Longman has already pointed out the correspondences between words of the "corroboree" song which Mrs. Smith sings and those of the "Song of the Aborigines of Van Diemen's Land", which was sung to Mrs. Logan by "Mifs", an aboriginal woman living in the Bothwell district between 1840 and 1850.

Both Fanny Smith and "Mifs" sing a melody which ascends, then descends to a reiterated ground tone. Triole rhythms and time-patterning are similar and the relation between words and melody syliabic.

Where there are marked divergencies, one is inclined to question the manuscript adaptions of an amateur pianist, rather than the memory of Fanny Smith.

Attention must be drawn to the fact that neither the "corroboree" nor the "legato" song styles, as recorded by Mrs. Smith, corresponds to descriptions of Tasmanian native singing by J. Bonwick[2]. He refers to rudimentary polyphonic effects, such as singing in thirds; also, songs which do not exceed the compass of a third. One can only speculate as to the nature of the occasions on which these apparently elementary song styles were performed. It may weli be that they were reserved for the sacred ceremonis in contrast to which were secular, or "popular" songs, of a more florid nature—songs which Fanny Smith preferred to sing. Or they may have been the songs of a different tribe with another dialect.

In tribal Australia, women and children are permitted to join in the "camp" or corroboree singing round the fires in the evenings. It may be that Mrs. Fanny Cochrane Smith learnt her songs when she listened as a child to singing and dancing among the native communities on Flinders Island.

An argument in favour of the authenticity of Mrs. Smith's native singing is the free style into which she lapses after what is, presumably, a European hymn. This is recorded on cylinder No. 8 (not transcribed). The wayward, improvisatory style, here, may be due to a reluctance, or inability, on the singer's part to proceed with a less familiar tune.

In the Federal Historical Library of the Australian Broadcasting Commission, there is a recording of a discussion between Norman B. Tindale[3] and an interviewer, Bob Lange, regarding possible descendants of the Tasmanian aborigines. Relevant to the discussion is a remark by Mr. Tindale that the first song (Example 1) is reminiscent of one of the Australian aboriginal songs heard on the West Coast of South Australia.

Despite the differences noted above between the two Tasmanian song styles, it is possible, I think, to isolate certain common features and to compare these with three selected Australian aboriginal songs, two of which were recorded on, or near, the West Coast of South Australia.

Scale tables, or reductions after the method suggested by Hornbostel[4], appear in Example 6 to assist in making this comparison. Consequently, some explanation of these and of signs in the transcriptions will first be given.

The durational values of each note in the scale indicate the relative frequency of the tones, i.e., the number of time these tones occur in the tune. The note judged to be the tonal centre, or key-note, usually occurs most often in the song and the melodies have been transposed so that each "tonic" appears as "middle c". A pause, or fermata, indicates the final tone; an inverted pause, the initial tone.

It will be noticed, for example, that in Example 6*b*, which is a reduction of the "Birds and Flowers" song, the beginning and ending tones coincide, whereas, in Example 6*c* they occur at opposite ends of the scale table.

In the transcriptions, an inverted "V" indicates Mrs. Smith's intake of breath; the "O" with horizontal line is for a hummed, or closed-mouth effect; small arrows indicate pitch deviations of less than a semitone and a diagonol line represents a vocal gliding, or glissando, effect.

Some deviations from the original pitch, during singing, cannot escape notice. For instance, in Fanny Smith's performance of the first song there is a gradual fall in pitch amounting to at least a semitone (100 cents). Such a situation is familiar to all who have listened to amateur performances by unaccompanied choirs. As it is not serious enough to conceal the intended melody, I have not shown the lapse in pitch in the transcription (Example 1).

The songs which have been reduced to the scale tables in Example 6 are as follow:

- 6*a* Tasmanian "corroboree" song (Example 2).
- 6*b* Tasmanian "legato" song (Example 5).
- 6*c* The Ship Song sung by an aboriginal woman from Yardea, Eyre's Peninsula, South Australia and recorded on wax cylinder by Professor E. Harold Davies[5] during expeditions 1927-29. A transcription of this song appears in Example 4.
- 6*d* A song by a Wirangu native from Denial Bay recorded in South Australia by Geoffrey O'Grady[6] in 1958.
- 6*e* A Kangaroo song sung by a Pidjindjara native and recorded in Central Australia by T. G. H. Strehlow[7] in 1952.

Regarding the two Tasmanian reductions, (6*a* and 6*b*) the central "tonic" clearly emerges, also the slight prominence given to the notes of the triad "A", "C" and "E". In contrast to this triadic base, the Australian songs give greater prominence to the fifth note above the 'tonic'.

(2) The daily life and origin of the Tasmanians, p. 30-32.

(3) Curator of Anthropology, South Australian Museum.

(4) Hornbostel, Erich M. von, and Abraham, Otto, Vorschläge zur Transcription exotischer Melodien (Sammelb. der Intern. Mus. Ges. XI), 1909.

(5) Aboriginal Songs (Oceania, II No. 4), 1932.

(6) Assistant to Dr. A. Capell, Reader in Oceanic Linguistics. Univ. Sydney.

(7) Reader in Australian Linguistics, Univ. Adelaide.

Un-Australian characteristics in the two Tasmanian songs include Fanny Smith's frequent intake of breaths. Records of Australian aboriginal soloists, male or female, and some of them well past middle age, demonstrate that singing "in one breath" (until the singer is silent through lack of it) is peculiar to Australian aboriginal singing.

The rising penultimate tone (see Example 1, bar 18; Example 2, bars 18 and 22; Example 5, bar 17) does not appear in the Australian examples shown here, though it has been heard, occasionally, in chants on the north-east coast of Arnhem Land([8]). The F sharp in Example 5, bars 8 and 13, need not be interpreted as a leading note in a major key, but rather as a lower, inflectional note.

Both the Tasmanian styles and the Australian "Ship Song" (Example 4) belong to the semitoneless pentatonic order. But songs which share in the pentatonic order can differ markedly in their melodic habits.

The general descending nature of th Australian song contrasts with the Tasmanian varieties which ascend as well as descend. An important similarity, however, is the addition of a subordinate descent at the close of the main song-descent. These tailpieces or "codas" are to be seen in Example 1 commencing at bar 14; Example 2, bar 18 and in the Australian Ship Song, Example 4, bars 7 and 28.

The Tasmanian samples, with their central tone, emphasis on a triad and upward thrust in the initial phrases, lead one to compare them with island styles further north.

The embellishments which cluster about the triadic base of the "Birds and Flowers" song bring to mind some of the singing styles heard in north-easterly New Guinea, also in New Ireland. Moreover, the "legato" example has that typical New Guinea division in its structure (compare bars 1-4 with 5-6) which prompts the use of such Western terms as "binary form", full or half close.

In the "legato" style the second part of the binary division recurs, after the manner of a refrain. If it had been possible for other Tasmanians to accompany Mrs. Fanny Smith, this song may have been sung in antiphonal, or responsorial style.

On one of the cylinders Horace Watson talks of the Tasmanians beating skins and sticks in accompaniment to their corroboree singing. Some faint percussive sounds—beating two against the singer's three—are to be heard on one or two places on these cylinders. Baldwin Spencer was more successful in his field recordings of accompanying instruments.

Even with the aid of available texts, my own efforts to fit the sung syllables to the sung tones was very soon abandoned. Apart from certain pairs of speech-sounds, such as the "ng-ya" which settled on the short-long (quaver-crotchet) tonal sequences in the "corroboree" style, and the first word "Popela", or "pappela" (which sounded contracted), I was unable to check consistently the words as Fanny Smith sang them.

Finally, it should be noted that bar-lines employed in the transcriptions do not imply regular metre, though this is often the case in the corroboree style. They are used chiefly to assist in identifying certain elements, rhythmic or melodic. Transposition signs at the commencement of Examples 1, 2 and 4 do not indicate "key". In the recording, Example 5 sounded about a half-tone flatter, but was raised in the transcription to reduce transposition signs.

## CONCLUSION

In its syllabic manner and additional descents, or "codas", the Tasmanian "corroboree" style resembles Australian aboriginal singing, particularly in South Australia and in the Centre. But the rising penultimate tone and triadic emphasis in the Tasmanian examples are not typical of Australian singing styles in general.

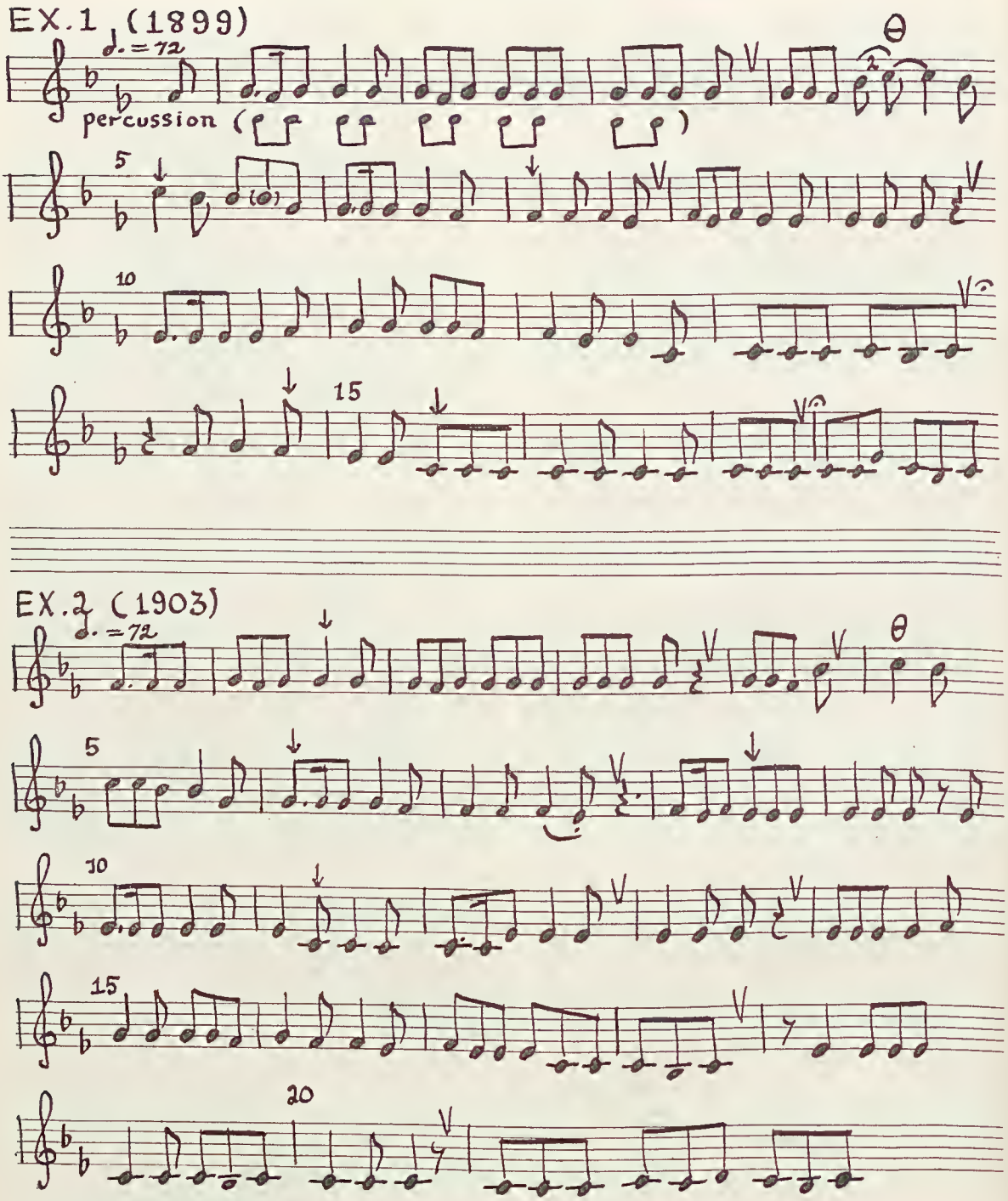
The "legato" Tasmanian song, with its central tonic, binary division and triadic base has more affinity with some New Guinea and possibly other island styles.

It may be concluded from these fragments, and from written reports by observers in the last century, that Tasmanian song-styles were widely varied. It seems that they ranged from monotone reiterations to songs of a relatively sophisticated nature such as the "legato" or "Spring" song.

## ACKNOWLEDGEMENTS

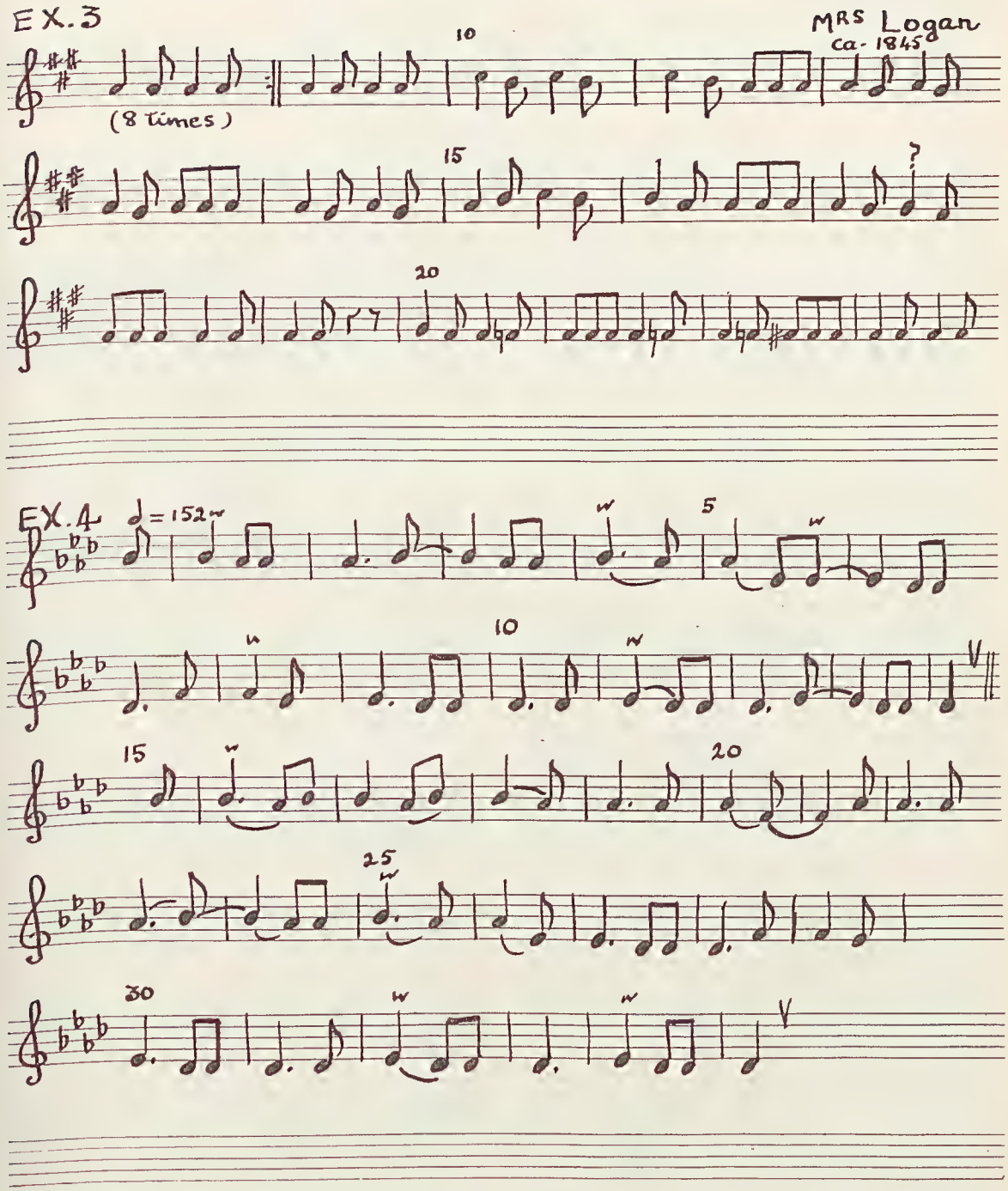
The writer wishes to acknowledge here the assistance received from the Research Grant Committee, The University of Sydney; further acknowledgement is made to Mr. M. J. Longman of the Tasmanian Museum for providing the tape copies of the cylinders on which this analysis is based.

([8]) Jiritja chants recorded by Professor A. P. Elkin (Sydney Univ. recordings).



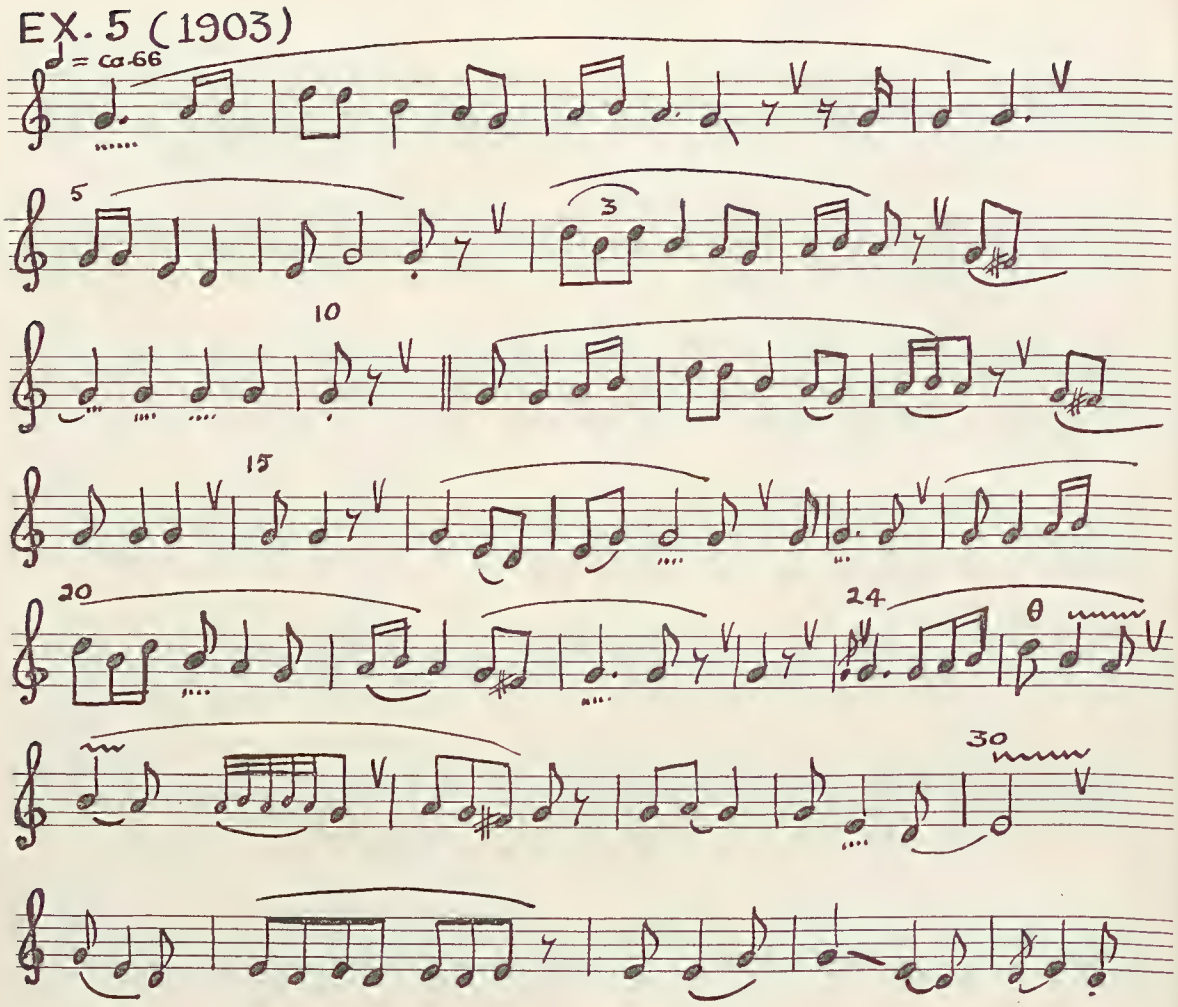

EXAMPLE 1.—Transcribed from Cylinder No. 1. The first version of the "corroboree" song style sung by Mrs. Fanny Cochrane Smith before members of the Royal Society of Tasmania in 1899.

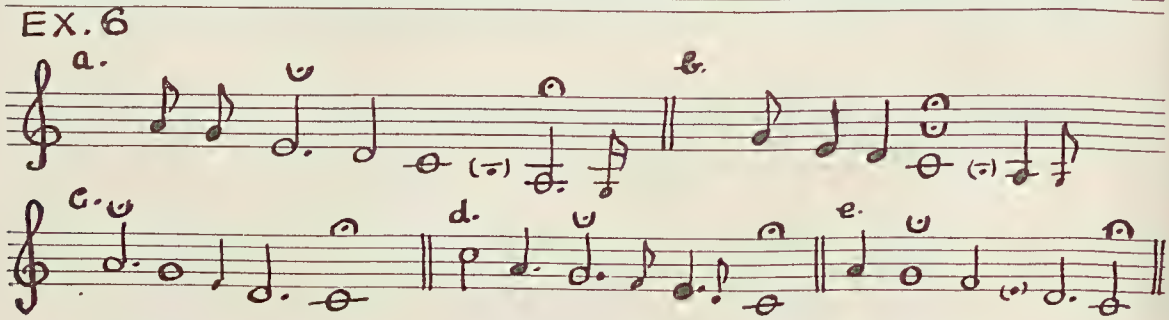
EXAMPLE 2.—Transcribed from Cylinder No. 4. "Dance Song", or second version of the corroboree song style sung by Fanny Smith and recorded by Horace Watson in 1903.




EXAMPLE 3.—Copied from Mrs. Logan's transcription of "A Song of the Aborigines of Van Diemen's Land" sung to her by "Mifs". Piano accompaniment has been omitted.

EXAMPLE 4.—"Ship Song" sung by an Australian aboriginal woman at Yardea, Eyre's Peninsula, S.A., and recorded by Professor E. Harold Davies on a phonograph in 1928. For re-recording on disc see Columbia (Aust.) P.R.X. 9-11.




EXAMPLE 5.—Transcribed from Cylinder No. 7. The song about "Birds and Flowers", or the "legato" song style sung by Fanny Smith and recorded by Horace Watson in 1903.

EXAMPLE 6*a-e*.—Scale Tables, see page 2, second column.

# SONGS OF THE TASMANIAN ABORIGINES AS RECORDED BY MRS. FANNY COCHRANE SMITH

By

Murray J. Longman.

*Tasmanian Museum, Hobart, Tasmania.*

(with two plates)

## ABSTRACT

Wax cylinders recorded by Mrs. Fanny Cochrane Smith in 1899 and 1903 were re-recorded using modern techniques.

This enabled re-interpretation and translation of the aboriginal spring and corroboree songs to be made and details of the introductory speeches by members of the Royal Society of Tasmania to be heard with reasonable clarity.

A brief historical note on Mrs. Fanny Cochrane Smith is included.

## INTRODUCTION

These unique recordings of the Tasmanian language were made in the years 1899 and 1903 by Mrs. Fanny Smith, who claimed to be the last of the Tasmanian aborigines. The wax cylinders were stored in the Tasmanian Museum and although re-recordings were made in 1909 by Horace Watson and again in 1948 for the Hobart meeting of A.N.Z.A.A.S., the cylinders have been neglected and no details of the contents published.

The 1948 attempts at re-recording were not completely successful and it was decided that recently developed techniques should be tried in an effort to improve the clarity of the originals.

## RECORDING TECHNIQUE

The equipment used to re-record these cylinders consisted of an Edison Phonograph with concert horn, and a high fidelity amplifier operated in conjunction with a tape recorder. Two copies were made from each cylinder.

As several cylinders were broken, these had to be repaired before they could be recorded. The pieces were arranged roughly in order on paper, then transferred and attached with an adhesive substance to the metal cylinder of the Edison Machine. It was found that the most suitable adhesive material was "Bear" Contact Cement. This is a rubber base cement which dries fairly slowly and sticks firmly to both the wax cylinder and the metal phonograph cylinder. Alignment of the wax pieces on the Edison metal cylinder, was accomplished with the aid of a magnifying lens.

The largest cracks in the wax cylinder and the holes where small fragments were missing were filled with a soft beeswax mixture which was levelled with the original surface. While the Edison machine turned very slowly the sapphire tip was guided through the soft wax surface to make a continuous groove about the record. The first few words of the wax recording were played at what was judged to be the correct speed and then any necessary adjustments to the speed were made.

Finally the whole cylinder was played and recorded on tape, note being made of any particularly bad sections and repetitions, which were improved if possible before the second playing by realigning the pieces of the record, and refilling the cracks with soft wax.

After the second copy had been taken the pieces were removed from the Edison machine in the reverse order of assembly. The pieces were slowly edged apart and finally pulled away from the machine. This task was made easier by the fact that the contact cement was not yet firmly set. Being of a rubber base, it stretched and broke and the small pieces of adhering rubber were removed from the record. By this method, all the broken cylinders were re-recorded and no new breakages occurred. With practice the whole assembly and recording of the broken cylinders took about one to one and a half hours.

As it was impossible to obtain an electric pickup for the Edison machine, acoustic methods had to be used for recording these cylinders. A high quality magnetic microphone was placed directly in front of the Edison horn and the output from this microphone was fed to a pre-amplifier which contained a noise limiting circuit, treble cut filter and bass cut filter.

The noise limiting circuit helped considerably in reducing the clatter caused by the cracks and scratches in the record, which were of a much higher level than the actual voices. Tests were carried out with the treble cut filter to determine the optimum upper frequency limit for recording. In this case it was found to be 5,000 cycles per second at which value some of the surface noise was eliminated but the voice was not materially affected.

The bass cut filter, which was eventually set at 300 cycles per second and left in that position for all the recordings, helped remove some of the mechanical noise from the machine.

The modified output from the preamplifier was fed to a high fidelity amplifier (distortion less than 0·5% at full output) connected to a magnetic tape recorder operating at 15" per second. One tape copy was kept as a spare and stored away; the

other was used to make additional tapes at 7½" and 3¾" per second, which were used in the interpretation of the words.

Acetate playback discs, made from the tapes, found only limited use in the interpretation of the original cylinders as they were more inconvenient to handle than the tape recordings.

Although the techniques used improved the clarity of the original cylinders the final products were still very poor because of the bad conditions of the originals. This was caused by Fanny Smith shouting whilst making the initial recording, and by speed variations in the machine. Later playing of the cylinders caused further deterioration of the speech.

## DETAILS OF THE RECORDINGS

### A. Recordings Made by Members of the Royal Society of Tasmania.

Cylinders 1, 2 and 3 were recorded on Saturday, 5th August, 1899 by members of the Royal Society of Tasmania in the Royal Society Room, Tasmanian Museum (Fig. 1).

The members present at the recording were the Bishop of Tasmania, the Rt. Rev. H. H. Montgomery; Mr. R. M. Johnston, the Registrar-General of Tasmania; Mr. A. Morton, Secretary of the Royal Society and Curator of the Tasmanian Museum; Mr. J. W. Beattie; Superintendent J. Cook; Mr. Fisher who operated the machine and Mr. J. B. Walker. This was the last official occasion upon which Mr. Walker appeared.

Mrs. Fanny Cochrane Smith was accompanied by her nephew.

*Record* 1 (15685/M3317).

This cylinder which was unbroken but in poor condition, consists of an introduction and song by Mrs. Fanny Smith. She speaks in English, answers several questions and concludes by singing her version of the "Corroboree Song" in the Tasmanian language.

> "I'm Fanny Smith. I was born on Flinders Island. I'm the last of the Tasmanians. I . . . the island . . . how about that. I'll tell you the truth, the truth . . . about us. My mother's name was Tangnarootoora. I . . . we are some true born sisters from Flinders Island, where we were for seven years and I am well, since good time".

A question is asked here.

> "You ask me if I remember my father? My father Noona. Noona not here. Noona, Noona gone. . . My father Noona. My father was a whaler, left my mother, all gone".

Another question is now asked.

> "My family? I'm married. Goodbye, my father, mother".

Fanny Smith now sings a version of the "Corroboree Song".

> "Pāpĕla rene nūena ne rene ne pāpĕla ne rene nūena ne rene
> Lŏga menxa leā
> Tóka menxa menxa leā
> Tóka menxa menxa leā
> Tóka menxa nára pewylā pālā nára pewylā pálawā
> Nīna nára pewylā pālā nára pewylā
> Pálawā pálawā".

*Record* 2 (15686/M3318).

There are frequent repetitions and omissions caused by the large cracks in this record interfering with the correct tracking of the stylus. The cylinder is broken into three large pieces and numerous small fragments.

Fanny Smith translates the "Spring Song" and concludes by singing this song in the Tasmanian language.

> "It's spring time,
> The birds is whistling,
> The spring is come,
> The clouds are all sunny,
> The fuchsia is out at the top,
> The birds are whistling,
> Everything is dancing,
> Because it's springtime,
> Everything is dancing,
> Because it's springtime".

Fanny Smith now sings:—

> "Niggur luggarato pawê,
> Punna mannakanna,
> Luggarato pawê tutta watta,
> Warrena pallanubranah,
> . . . . . ,
> Punna munnakanna,
> . . . . rialangana,
> . . . . luggarato pawê,
> . . . . rialangana,
> Luggarato luggarato luggarato".

*Record* 3 (15687/M3319).

Although this record is unbroken, it is in very poor condition and in many places the background noise is greater than the speech level. Members of the Royal Society speak in appreciation of Mrs. Fanny Smith for agreeing to make these records.

The first speaker is the Bishop of Tasmania, the Rt. Rev. H. H. Montgomery, Vice-President of the Royal Society of Tasmania.

> "It has been my great privilege today, the fifth of August, 1899, to have witnessed Mrs. Fanny Smith of Port Cygnet, who claims to be the last member of all the native races of this island, sing and speak into the gramophone. I have also taken a photograph showing her sitting by the machine. I feel very glad indeed that the aboriginal language of these islands, together with its songs, however fragmentary the results may be, have at least been permanently registered and can be preserved and listened to in future years, when this, and the remaining representatives of the native

race, have passed away. I think the Secretary of this Society, the Royal Society of Tasmania, Mr. Alexander Morton is deserving the thanks of scientific men and all true colonists for bringing about such a valuable and unique contribution to the records of this Colony. R. M. Johnston, Government Geologist".

The Bishop concludes by introducing Mr. R. M. Johnston, the other Vice-President of the Society.

"I, Robert M. Johnston, Registrar-General of Tasmania, have also the great privilege and pleasure of hearing the songs of the native Tasmanians sung by the last of the souls in the way of the phonograph. This will be of great interest to those who are studying the various races of mankind now".

The Secretary of the Royal Society of Tasmania, Alexander Morton concludes:

"Alexander Morton, Secretary of the Royal Society of Tasmania endorses the . . . words of R. M. Johnston, Vice-President of the Royal Society, in having had the pleasure of listening to the songs and words of Mrs. Fanny Smith, who claims to be the last of the Tasmanian aborigines. These songs and words have been recorded in the Royal Society Rooms, Hobart, Tasmania, on Saturday the fifth of August in the presence of His Lordship, the Bishop of Tasmania, the Rev. H. H. Montgomery, Mr. J. B. Walker, F.R.G.S., Mr. R. M. Johnston, Editor . . .".

The record finishes at this point before the conclusion of Alexander Morton's speech.

**B. Recordings made by Horace Watson, Sandy Bay, 1903.**

Cylinders 4, 5 and 6 were made by Horace Watson. Mrs. Smith recorded these cylinders at his home, Barton Hall, Sandy Bay, Hobart, Tasmania, on Thursday, 8th October and again on Saturday, 10th October, 1903 (Fig. 2).

These cylinders were used for later copies made by Horace Watson for Robert Hall, Curator of the Tasmanian Museum.

*Record* 4 (15688/M3320).

This cylinder is complete and in fair condition. Fanny Smith, introduced by Horace Watson, sings the "Corroboree Song". Particulars of the recording are given by Horace Watson and Fanny Smith makes a final statement.

"This record by Fanny Smith, daughter of Tangnarootoora, presents the song of the natives, when holding their corroboree, who endeavour to sing with all their might, accompanied by the beating of sticks and skins. This is a dance song by Fanny Smith".

Fanny Smith now sings the "Corroboree Song" in the Tasmanian language.

"Pāpĕla rene nūena ne rene ne pāpĕla rene nūena ne rene ne
Lŏga menxa leā
Tóka menxa menxa leā
Tóka menxa menxa leā
Tóka menxa menxa leā
Tóka menxa menxa leā
Tóka menxa nára pewylā pālā nára pewylā pálawā pálawā
Nīna nára pewylā pālā nára pewylā pálawā pálawā".

Horace Watson continues with details of the recording.

"This record was taken on October the tenth, 1903, by Horace Watson, Sandy Bay, Hobart, Tasmania".

Fanny Smith concludes by stating:—

"I am the last of the race, a Tasmanian. I am, I am the daughter of Tangnarootoora, of the East Coast Tribe. I am just seventy years of age".

*Record* 5 (15689/M3321).

After an introduction by Horace Watson Fanny Smith sings the "Spring Song". About twelve words from the end of the song are missing, because a large piece, broken off the cylinder has been lost.

"This record of Mrs. Fanny Smith, sister of Mary-Ann, wife of Walter Arthur and daughter of Tangnarootoora, presents the song of the aborigines at the time of the spring, welcoming the advent of the birds and flowers".

Fanny Smith now sings the "Spring Song" in the Tasmanian language.

"Niggur luggarato pawê,
Punna munnakanna,
Luggarato pawê tutta watta,
Warrena pallanubranah . . . .".

The record is broken at this point.

*Record* 6 (15690/M3322).

This cylinder, which was shattered into six large pieces and many small fragments, is a recording of abreviated forms of the "Corroboree" and "Spring Songs". Each song is introduced by Horace Watson. As the repaired cylinder could only be played once, no correction for speed could be applied, and so the speech is distorted. The numerous cracks make interpretation even more difficult and only a few phrases can be distinguished.

"This record by Mrs. Fanny Smith, daughter of Tangnarootoora presents the song of the natives, when holding their corroboree, who endeavour to sing with all their might accompanied by the beating of sticks and skins".

Fanny Smith sings the "Corroboree Song".

Horace Watson introduces the second song.

". . . daughter of Tangnarootoora . . . song of the . . . welcoming the advent of birds and flowers".

Fanny Smith now sings the "Spring Song".

**C. Re-recordings made by Horace Watson, 1909.**

These two cylinders were made for Mr. Robert Hall, onetime curator of the Tasmanian Museum by Horace Watson. When Mr. Hall left the Museum his private collection was brought by Mr. Sargison of Hobart and these records remained in his possession until recently, when he presented them to the Tasmanian Museum.

## Interpretation of Tasmanian Aboriginal Songs.

| J. W. Walker 1832* | R. Davis 1846* | Mrs. Logan 1840-50* |
|---|---|---|
| Pōppylă-rēnŭng-onnynă | Ne popila raina pogana | Pope la ranea gone na |
| Poppyla-renung-onnyna | Ne popila raina pogana | Pope la ranea gone na |
| Poppyla-renung-onnyna | Ne popila raina pogana | |
| Lēmĭngānnyă | Thu me gunnea | Lea me gone-na |
| Lemingannya | Thu me gunnea | Lea me gone-na |
| Lemingannya | Thu me gunnea | |
| Tāūkŭmmĭngannyă | Thoga me gunnea | Toka me gunne a |
| Taukummingannya | Thoga me gunnea | Toka me gunne a |
| Taukummingannya | Thoga me gunnea | |
| | | Lea me gunne a |
| | | Lea me gunne a |
| Nynă tēpē rēnĕ pōnnynă | Naina thaipa raina pogana | Nina tepea ranea ponena |
| Nyna tepe rene ponnyna | Naina thaipa raina pogana | Nina tepea ranea ponena |
| Nyna tepe rene ponnyna | Naina thaipa raina pogana | Nina tepea ranea |
| Nynă nāră pēwĭlly pāră | Nara paara poiwella paara | |
| Nyna nara pewilly para | Nara paara poiwella paara | |
| Nyna nara pewilly para | Nara paara poiwella paara | |
| Nāră pēwĭlly pāllăwŏŏ! | Ballahoo, ballahoo | |
| pāllăwŏŏ! | Ballahoo, ballahoo | |
| | Ballahoo, ballahoo | |
| Nynă nāră pēwĭlly pāră | Hoo hoo | Nina nara burvilla pana |
| pēwĭlly pāllăwŏŏ pāllăwŏŏ! | | nara burvilla ballahoo! |
| Nyna nara pewilly para | Hoo hoo | ballahoo! |
| pewily palawoo palawoo | | Nina nara burvilla pana |
| Nyna nara pewilly para | Hoo hoo | para burvilla ballahoo! |
| pewilly pallawoo pallawoo | | ballahoo! |

NO OTHER RECORD OF THIS SONG HAS BEEN FOUND.

| J. Milligan 1859* | Fanny Smith 1899† | Fanny Smith 1903† |
|---|---|---|
| Pāppĕlă Rāynă 'ngōnynă,<br>Pāppĕlă Rāynă 'ngōnynă,<br>Pappela Rayna 'ngonyna! | Pāpĕla rene nūena<br>ne rene ne pāpĕla<br>ne rene nūena ne rene | Pāpĕla rene nūena ne<br>rene ne pāpĕla rene<br>nūena ne rene ne |
| | Löga menxa leā | Löga menxa leā |
| Tōkă mēnghă lēăh,<br>Tōkă mēnghă lēăh,<br>Toka mengha leah! | Tóka menxa menxa leā<br>Tóka menxa menxa leā | Tóka menxa menxa leā<br>Tóka menxa menxa leā<br>Tóka menxa menxa leā<br>Tóka menxa menxa leā |
| Lūghă mĕnghă lēăh,<br>Lūghă mĕnghă lēăh,<br>Lugha mengha leah! | | |
| Nēnă tāypă rāynă poōnynă,<br>Nēnă tāypă rāynă poōnynă,<br>Nena taypa rayna poonya! | | |
| Nēnă nāwră pēwyllăh,<br>Pāllăh nāwră pēwyllăh,<br>Pēllăwăh Pēllăwăh!<br>Nena nawra pewyllah,<br>Pallah nawra pewyllah,<br>Pellawah Pellawah! | Tóka menxa nára<br>pewylā pālā nára<br>pewylā pálawā<br>Nīna nára pewylā<br>pālā nára pewylā<br>pálawā pálawā | Tóka menxa nára pewylā<br>pālā nára pewylā<br>pálawā pálawā<br>Nīna nára pewylā<br>pālā nára pewylā<br>pálawā pálawā |
| | | Niggur luggarato pawê‡<br>Punna munnakanna<br>Luggarato pawê tutta watta<br>Warrena pallanubranah<br>. . . . . .<br>Punna munnaganna<br>. . . . rialangana<br>. . . . luggarato pawê<br>. . . . rialangana<br>Luggarato luggarato luggarato |

* Spelling and phonetics as in the original.
† Author's interpretation of songs on wax cylinders using Schmidt's vocabulary.
‡ Author's interpretation of song using Milligan's vocabulary.

*Record* 7 (15691/M3323).

Made from hard black material similar to commercial records, this cylinder is complete and in good condition. Horace Watson introduces Fanny Smith, who sings the "Spring Song" and he concludes by giving details of the recording.

> "This record of Mrs. Fanny Smith, sister of Mary Ann, wife of Walter Arthur and daughter of Tangnarootoora presents the song of the aborigines at the time of the spring welcoming the advent of birds and flowers".

Fanny Smith now sings the complete version of the "Spring Song".

> "Niggur luggarato pawê,
> Punna munnakanna,
> Luggarato pawê tutta watta,
> Warrena pallanubranah,
> . . . . . ,
> Punna munnakanna,
> . . . . rialangana,
> . . . . luggarato pawe,
> . . . . rialangana,
> Luggarato luggarato luggarato".

Horace Watson now states the details of the recording.

> "This record was taken on October the eighth, 1903, by Watson, Barton Hall, Sandy Bay, Tasmania.
>
> This record was taken off the original . . .".

*Record* 8 (15692/M3324).

This cylinder has one crack along its entire length and another at the beginning. The condition is very poor and many words are completely distorted because of the larger crack.

Fanny Smith introduced by Horace Watson, commences to sing a hymn, but after the first few phrases reverts to the aboriginal style of singing. Details of the recording are given at the end by Horace Watson.

> "This record, sung by Mrs. Fanny Smith, the daughter of Tangnarootoora of the East Coast Tribe.
>
> Praise the Lord,
> Hail the Lord,
> Abide in Heaven above".

Fanny Smith now commences to sing this hymn. but quickly reverts to the aboriginal style of singing. The only recognisable phrase is "Praise the Lord".

Horace Watson now concludes:

> "This record was made for me by Fanny Smith in 1903. We had a real excellent time here. You will see the photograph taken in the very action of singing.
>
> This record was taken from the original on May the sixth, 1909, for Mr. Robert Hall, Curator of the Tasmanian Museum by Horace Watson Sandy Bay,".

## TRANSLATION OF THE SONGS

Fanny Smith translates the Spring Song on record 2 but there is no translation of the Corroboree Song as this record was broken and is now lost.

Comparison of Fanny Smith's version of the Corroboree Song with the other recorded version shows that she was improvising and knew only a few phrases of the song. This fact is also supported by the variation shown in the songs of record 1 and 4.

For the purpose of translation Milligan's version was used as this contained all the phrases sung by Fanny Smith. Milligan also states that this song was to honour a great chief.

*Corroboree Song* (without repetitions)

> Pappela rayna ngonyna,
> fast run fire,
> The camp fire burns fast,
> Toka mengha leah, Lugha mengha leah,
> Heel toe behind, Foot toe behind,
> Heel, toe behind, Foot, toe behind
> Nena taypa rayna poonya
> You come run bird,
> You come and run like a bird,
> Nena nawra pewyllah, Pallah nawra pewylla, Pellawah, Pellawah,
> You very man, Man very man, great man, great man
> You are a brave man, a brave man, a great man, a great man.

*Spring Song.*

> Niggur luggarato pawê,
> It wattle blossom time
> It's spring-time,
> Punna munnakanna,
> bird whistle
> The birds are whistling,
> Luggarato pawê tutta watta,
> spring come
> Spring has come,
> Warrena pallunubranah,
> cloud sun
> The clouds are all sunny,
> .. .. .. .. .. ..
> .. .. .. .. .. ..
> The Fuschia is out at the top,
> Punna munnakanna,
> bird whistle
> The birds are whistling,
> .. .. .. rialangana,
> .. .. .. dance
> Everything is dancing,
> .. .. .. luggarato pawê
> .. .. .. spring-time
> Because it's spring-time,
> .. .. .. rialanganna,
> .. .. dance
> Everything is dancing,
> Luggarato luggarato luggarato,
> spring spring spring
> Because it's spring-time.

## HISTORICAL NOTE ON FANNY COCHRANE SMITH

There is no official record concerning the date of Fanny Smith's birth, but according to her own statements, she was born in 1833 or 1834. Her death certificate indicates her birth year about 1831 but Mrs. Meredith, midwife who assisted at her birth, said that it was 1836.

Fanny Smith's mother was a full-blooded aborigine called Sarah (native name Tangnaroo-toora), but there is some doubt as to the identity of her father. Sarah first lived with a white sealer and became the mother of four half-caste children, one of whom was called Mary-Ann. She later lived with an aboriginal man, Eugene, on Flinders Island where she gave birth to a further three children, named Fanny, Adam and Duke. Some authors suggest that Fanny's name Cochrane was given to her by Cottrel Cochrane, the sealer who lived with Sarah, but in other reference it is stated that Cochrane was the maiden name of Mrs. Clarke, wife of the catechist of Flinders Island, and that this name was given to Fanny while she was in the Clarkes' care.

The first official reference to Fanny is a letter dated 8th December, 1842, which conveyed approval for admission into the Queen's Orphan School of three aboriginal children, Fanny, Martha and Jesse. Also in the official records of the same date is an application from Mr. R. Clarke for permission to receive into his family "an aboriginal child named Fanny . . .".

In the next account an official document dated 8th March, 1847, these words appear, "Eugene and his wife, father and mother of Fanny and Adam . . .".

A report made by Dr. Jearnneret, the Superintendent of Flinders Island, and dated March 25th, 1847, contains the following statement signed by Fanny Cochrane.

"I am a half-caste of Van Diemen's Land. My mother is a native, I am about 13 years of age".

Dr. Milligan in a long report of 29th November, 1847, on the occasion of the removal of the natives from Flinders Island to Oyster Cove, mentions that "The fifth girl Fanny Cochrane, almost a woman might remain with her half sister Mary-Ann".

In 1853 Fanny became acquainted with William Smith, sawyer from North West Bay, and in an official letter dated 17th July, 1854, Dr. Milligan enclosed William Smith's consent to marry Fanny Cochrane, whom he describes as an aboriginal girl from Oyster Cove. Also Dr. Milligan arranged for Fanny to receive a grant of £24 p.a. on the occasion of her marriage, the grant being the equivalent of the cost of keeping her at Oyster Cove.

William Smith and Fanny Cochrane were married on 27th October, 1854, by the Rev. F. Miller at the minister's house in Murray Street, Hobart, with Joseph Milligan and J. J. Salier witnesses. Dr. Milligan gave the bride away.

William and Fanny Smith then returned to North West Bay for six to nine months before moving to Hamilton where they remained for two years in the employ of Mr. William Clarke of Norton Mandeville.

In 1857 they went to Hobart and opened a boarding house in Liverpool Street. However this venture was not a financial success, mainly owing to the visits of natives from Oyster Cove, who apparently received free board with the Smiths.

They then returned to North West Bay where they lived for a few months. During this time Fanny's brother Adam, visited them and he died on 28th October, 1857, aged 20 years. He was attended by Dr. Smith of Browns River, his mother Sarah, his sister and her husband.

Shortly afterwards William and Fanny moved to Irish Town (now Nicholls Rivulet) and on 1st August, 1858, Fany's first child was born. During this time Sarah lived almost continually with her daughter.

Whilst on a short visit to Oyster Cove, Sarah was taken ill and on 3rd October, 1858, at the age of about 62 years, she died. During her brief illness she had been waited upon by Fanny, William and Mary-Ann.

William and Fanny then went to live permanently at Irishtown, her last child being born there in 1877.

In all, their family numbered eleven children—six boys (William, Peter, Joe, Walter, Charles and Fred) and five girls (Sarah, Flora, Bella, Laura and Mary).

Fanny firmly believed that she was a full-blood aborigine and on 14th September 1882, on the motion of Mr. Burgess, a Parlamentary Committee met at consider an address to the Governor for an additional £26 p.a. for her. Satisfied after due enquiry, that Fanny Smith was actually the last Tasmanian aborigine, Parliament resolved that the supplementary annuity be sought.

However people who had known her on Flinders Island and at Oyster Cove did not agree with this decision. Mr. A. E. Walpole, Police Magistrate of Franklin who paid monthly visits to Oyster Cove, wrote "I have known Fanny Smith (ne Cochrane) for some 27 years. She is a half-caste born of an aboriginal woman by a white man (whose name is unknown)". Mr. H. Robinson, son of the protector of the aborigines, stated that he remembered Fanny Cochrane well, that she was a half-caste and her mother was "married" to a prisoner of the crown.

In 1884 Parliament passed another resolution granting Fanny Smith 200 acres of land in addition to the 100 acres she already owned, the reason again being that she was the last survivor of the aboriginal race.

During the latter part of her life both she and William became converts to Methodism, and her eldest son eventually became the local Methodist minister. Church services were held in the large kitchen of her house while the barns and paddocks were sites for Sunday school picnics. She was a very popular person on the district and using her barn as an improvised concert hall, she would entertain by singing her native songs.

In 1899 she recorded her songs for the Royal Society of Tasmania and again in 1903 for Horace Watson of Sandy Bay, who regularly gave concerts with his Edison phonograph.

Fanny Cochrane Smith died of pleurisy and pneumonia on 24th February, 1905 at Port Cygnet. She had been attended by Dr. Thomas.

Her descendants still live at Nicholls Rivulet on the land originally granted to her. The present church and the land on which it stands at Nicholls Rivulet was provided by Fanny Smith and her photograph hangs in the Church.

## ACKNOWLEDGEMENTS

The author wishes to thank the Trustees of the Tasmanian Museum who made the re-recording of the cylinders possiblie, also the Australian Broadcasting Commission, Cadbury-Fry-Pascall Ltd., Commercial Broadcasters (7HO) Pty. Ltd. and the Hydro-Electric Commission for the use of equipment and technical advice.

Details about Mrs. Fanny Smith were received from Mrs. L. Luckman and Mr. E. R. Pretyman while Mr. T. Smith and Mr. B. Miller of Nicholls Rivulet gave further information. Miss E. Geddes and my wife helped with the interpretation of the words and songs recorded on these cylinders.

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FIG. 1.—Mrs. Fanny Cochrane Smith recording the aboriginal songs for members of the Royal Society of Tasmania on August 5th, 1899. *Left to right*—Mr. R. M. Johnston, Mr. J. W. Beattie (behind), Mr. Fisher, Superintendent J. Cook, Mr. Alex Morton, Mr. J. B. Walker, Mrs. Fanny Cochrane Smith, her nephew.

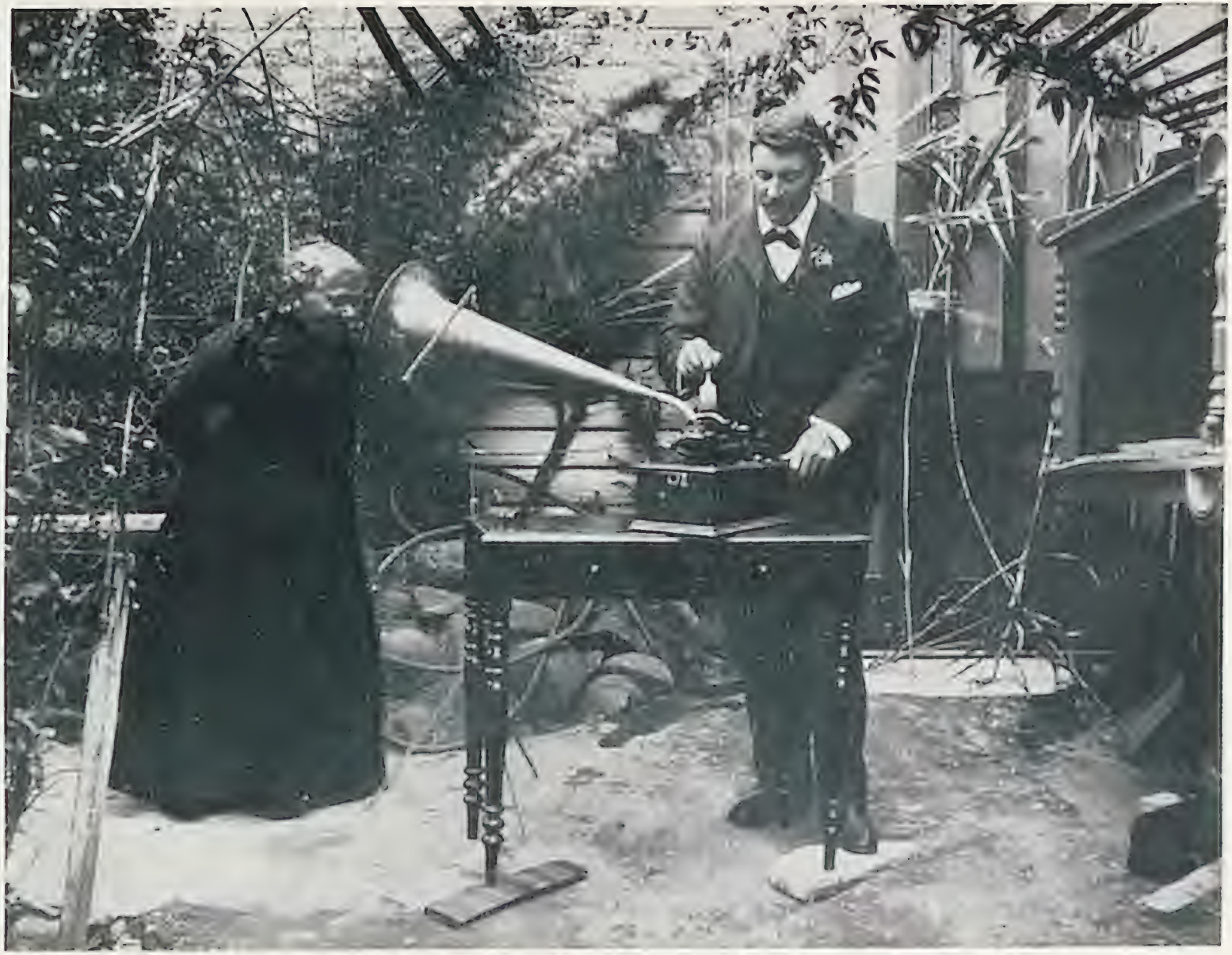

Fig. 1. Mrs. Fanny Cochrane Smith recording aboriginal songs for Horace Watson, Sandy Bay, 10.1[illegible].

# OBSERVATIONS ON SOME TASMANIAN FISHES: PART IX

By

E. O. G. Scott

One text figure

## ABSTRACT

A case of mass mortality in *Navodon setosus* (Waite), 1899 [Aluteridae], a species now first formally recorded from Tasmania, is reported: some features of two juveniles are described and figured. Taxonomic data on *Mitotichthys tuckeri* (Scott), 1942 [Syngnathidae], hitherto known only from the holotype, are extended by an account of two virtual topotypes. Miscellaneous observations are made on *Stigmatopora argus* (Richardson), 1840 [Syngnathidae] (status of several species commonly reduced to synonymy); *Lampris regius* (Bonnaterre), 1788 [Lampridae] (third Tasmanian record; dimensions); *Dactylosargus arctidens* (Richardson), 1839 [Aplodactylidae] (differences from published accounts and figures; general observations); *Lepidopus caudatus* Euphrasen), 1788 [Trichiuridae] (dimensions); *Pseudaphritis urvillii* (Cuvier & Valenciennes), 1831 [Pseudaphritidae] (correction of standard figures); *Gymnapistes marmorata* (Cuvier & Valenciennes), 1829 [Scorpaenidae] (variation, coloration, behaviour). Keys to the Tasmanian members of the families Scorpaenidae, Aluteridae are provided.

This contribution follows the general pattern of others in the series. As before, standard length, total length are denoted by *Ls*, *Lt*, respectively: all linear dimensions are given in millimetres, the name of the unit customarily being omitted.

Two new conventions are introduced. (*a*) *Specification of members of a series.*—Where two, or more, specimens are noticed in the one context, the sequence of citation of the relevant specification is that of increasing size of individual fish, as measured by *Ls* (rarely, if *Ls* is not determinable, by *Lt*). (*b*) *Designation of localities.*—The general practice hitherto followed of recording Tasmanian localities in the form exemplified by 'Devonport, North West Coast' is now superseded by the employment, for the second, more general specification, of the county name. This procedure offers two advantages. First, it is more precise. Secondly, it avoids certain ambiguities arising from some local usages, in which the terms to be replaced are applied to districts the limits of which are not by any means necessarily inherent in the designations. Thus Devonport, Lat. 41° 12′ S., Long. 146° 21′ E., is on the north coast, nearer in a direct line to the north-east corner of the Island at Cape Portland than to the north-west corner at Cape Grim; and Railton, Lat. 41° 21′ S., Long. 146° 26′ E., lies a dozen miles from the sea; the conventional location of both, however, is 'North West Coast'. Again, Bridport, Lat. 41° 01′ S., Long. 147° 23′ E., and St. Helens, Lat. 41° 20′ S., Long. 148° 14′ E., are approximately equidistant—westward, southward, respectively—from Cape Portland; yet the former is a 'North East Coast', the latter an 'East Coast', town: Stanley, Lat. 40° 47′ S., Long. 145° 19′ E., which stands in about the same relation to Cape Grim as Bridport does to Cape Portland, belongs to the 'Far North West'.

Entries in tables of synonymy, particularly citations from the earlier authors, are not necessarily identical with the originals in point of typographical detail (earlier employment of initial capitals for some trivial names; no general, or indescriminate use of parentheses; and so on); being rendered in a standard pattern in accord with contemporary conventions.

## Family SYNGNATHIDAE

In the Australian Check List (McCulloch, 1929) seven species, representing six genera, are accredited to Tasmania: these totals have now been increased (largely in the present series of studies) to fifteen species and (on conservative taxonomy) ten or eleven genera. For keys see Scott (1939: 140; 1942*a*: 19; 1955: 135): note, however, the presence of more than thirty dorsal rays in *Mitotichthys tuckeri* (Scott) leads to invalidation of second clause of couplet 8 in the 1939 key.

## Genus Mitotichthys Whitley, 1948

### Mitotichthys tuckeri (Scott), 1942

*Syngnathus tuckeri* Scott, 1942, *Rec. Queen Vict. Mus.*, I, i: 17, pl. V. Type locality: Bridport, Northern Tasmania [Dorset]; netted in shallow water.

*Mitotoichthys tuckeri* (Scott). Whitley, 1948, *Rec. Aust. Mus.*, XXII, 1: 75.

*Generic status.*—Until a complete review of Australian pipefish genera in the light of recent advances in Syngnathid systematics—in particular the full diagnostic use of variations in brood pouch morphology and egg distribution: see, *e.g.*, Herald (1953)—has been made, the true generic status of a number of our pipefishes (including even some long-established species, for which the newly relevant data is not recorded in the literature) must unfortunately remain more or less obscure. From *Syngnathus* Linné, as understood by, *e.g.*, Weber & De Beaufort (1922) the present form departs in several particulars, most notably perhaps in the location of the dorsal fin.

*Virtual topotypes.*—The species appears not to have been reported since its publication in 1942, and has hitherto been known only from the unique holotype, a male, *Ls* 121·3, *Lt* 126·6. Our existing knowledge is now usefully supplemented by the receipt of two virtual topotypes, both secured at Piper River Heads, Dorset, about a dozen air-miles westward from the type locality, Bridport: (*a*) female, *Ls* 91·2, *Lt* 95·6, collected by Master Hugh Holyman in 1956; (*b*) male, *Ls* 126·9, *Lt* 132·4, caught in a permanent rock-walled fish trap by Mr. J. Allchin on 4th November, 1957. No evidence has come to light, it will be noted, to suggest the species is of other than smallish size.

*Proportions, meristic characters.*—A brief comparison of the three known individuals [in sequence (*a*), holotype, (*b*)] follows: in present paragraph dimensions of Piper River Heads specimens (only) are recorded in parentheses, other values being body proportions of all examples. Head (13·1, 16·1) 2·9, 3·0, 3·2 in length to vent ( 38·6, 52·0); 7·0, 7·6, 7·9 in length to base of caudal (91·2, 126·9); 7·3, 7·9, 8·2 in total length (95·6, 132·4). Eye (2·0, 2·3) 3·1, 3·1, 3·3 in snout (6·2, 7·7), which is 2·1, 2·1, 2·1 in head. Depth at opercular margin (3·0, 4·4) 32, 32, 30; at middle of trunk (3·0, 3·3) 32, 33, 40; at vent (2·2, 3·0) 44, 37, 44; at middle of tail (1·5, 1·9) 64, 79, 71, in total length. Vertical height of dorsal [*i.e.*, as preserved] (2·4, 4·0), 5·1, 4·2, 4·3 in its base (12·3, 17·3), which is 2·4, 2·2, 2·2 in its distance from snout (29·9, 38·3). Pectoral (3·1, 4·8) 4·7, 3·6, 3·4; caudal (4·4, 5·5) 3·0, 3·0, 2·9, in head. Interorbital width (1·0, 1·3) 2·0, 1·5, 1·8 in eye. Base of pectoral (1·9, 2·4) 1·6, 2·5, 2·0 in fin length.

Annuli 22 +40, 23 +42, 22 + 41. Subdorsal annuli 10·0 + 2·3, 10 + 2 (fractions not recorded), 9·8 + 1·9. Brood annuli none, caudal 1-12, caudal 1·0-11·4. Dorsal 35, 35, 35. Pectoral 12, 11, 12. Anal not found.

Superolateral trunk ridge extends on to 0·4 of, on to (faction not recorded), to 0·4 of first caudal scute (on left side of (*b*) only to 0·7 of last body scute): mediolateral trunk ridge terminates on 0·5 of last, on penultimate, on 0·8 of penultimate trunk scute (tip turning down slightly in (*a*) and on left side of (*b*); no record for holotype): superolateral caudal ridge originates on left side at 0·9 of penultimate, middle of antepenultimate, 0·4 of penultimate, and on right side at 0·4 of last, front of penultimate, 0·5 of penultimate trunk scute; inferolateral ridge of trunk and tail continuous in female, apparently continuous (brood pouch interposed) in both males: medioventral ridge of all specimens well defined on trunk, obsolescent on tail.

*Comment on, and additions to, original description.*—Diagnosis states concerning dorsal, 'base not distinctly elevated' (1942: 17). This correctly describes the position in so far that, in strict lateral aspect, the portion of the dorsal profile on which the fin stands is not greatly higher than its immediate cephalad and caudad extensions: on the other hand, it fails at this point of the text and in the general account of the dorsal fin (1942: 18) (though the relevant datum appears elsewhere) to make clear the fact that, as a result of the continuation (without loss of height, relative to inferolateral ridge) of the superolateral trunk ridge (which anterior to the fin virtually constitutes the dorsal profile) on to the lateral surface of the body—a continuation extending from level of origin of fin caudad through some eight or nine annuli—the anterior four-fifths or so of the fin base comes to lie measurably above this ridge, and may accordingly be regarded as being elevated. No reference is made in original description to presence or absence of lateral protective brood plates: examination of (*b*) shows none are developed.

After (*b*) was placed in preservative the spindle-shaped egg mass worked clear of pouch: eggs are imbedded in a more or less distinctly cellular jelly-like matrix; three, perhaps four, rows near middle, fewer at either end; chiefly in one layer, centrally in two (at least). Dorsal wall of pouch with from one to three more or less well-defined series of shallow, low-walled subcircular or polygonal depressions: inner surface of each pouch fold divided by about 15 low transverse ridges into subrectangular compartments, their inner ends continuous with the mesial honeycomb-like band.

## Genus Stigmatopora Kaup, 1853

### Stigmatopora argus (Richardson), 1840

*Syngnathus argus* Richardson, 1840, *Proc. Zool. Soc. Lond.*, VIII: 29. Type locality: not specified [= Tasmania; McCulloch (1929)].

*Stigmatophora argus* (Richardson). Munro, 1958, *Handbk Aust. Fish.*: 90 [instalment no. 22 in Fisheries Newsletter, XVII, 4, April, 1958: 18].

*Status of various species of Stigmatopora.*—Since Waite and Hale's (1921) survey of the Lophobranchiates of South Australia, it has been customary to recognize only two Australian species of *Stigmatopora*—*S. argus* (Richardson), 1840 and *S. nigra* Kaup, 1853. The latter (which has been referred to a subgenus, *Pipettella* Whitley, 1951, later elevated to a genus, *Nigracus* Whitley, 1953) is tolerably well defined, with as its only notable synonym *S. boops* Castlenau, 1872. With *S. argus* Richardson, however, Waite & Hale synonymized *S. olivacea* Castlenau, 1872, *Gasterotokeus gracilis* Klunzinger, 1872, *S. unicolor* Castlenau, 1872, *S. depressiuscula* Macleay, 1881, *S. gracilis* Macleay, 1881, *S. argus* var. *brevicaudata* Lucas, 1891.

A specimen of a *Stigmatopora* collected by Mr. B. C. Mollison at Chimney Corner, Three Hummock Island, Bass Strait, exhibits a disconcerting assortment of characters. Waite & Hale's consideration of the forms of Macleay and Lucas is confined to coloration and to number of caudal annuli (low totals reported by some authors being attributed by them to mutilation): certain other significant points of divergence are not discussed. Examination of Mr. Mollison's specimen suggests the question of the conspecificity of these half dozen nominal species could perhaps profitably be reopened. A comparative synopsis of characters is set out in Table 1.

TABLE 1

CHARACTERISTICS OF *Stigmatopora argus* (RICHARDSON), 1840 AND OF SOME FORMS COMMONLY REGARDED AS CONSPECIFIC

| SPECIES [and Chimney Corner Specimen] | CHARACTERISTIC | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Annuli | Dorsal Rays | Opercular Ridge | Rest of Head in Snout | Trunk in Tail | Part of Dorsal above Vent | Colour Markings | Brood Pouch | Miscellaneous |
| *S. argus* Richardson | 20+*ca* 75 | 49–52 | Slight ridge in young, almost entirely disappearing in old individuals | *ca* 2 | > 2 | Middle | Uper surface with numerous small black white-edged ocelli, arranged irregularly, or in longitudinal, or transverse, series | Shorter than trunk | .. |
| *S. olivacea* Castelnau | 19+84 | *ca* 45 | No ridge | Rather > 2 | .. | Middle | Inconspicuous transverse bands at junctions of annuli and on snout | On 13 rings | Brood pouch orange |
| *S. unicolor* Castelnau | 17 | .. | Strong distinct longitudinal, rather oblique ridge | 1½ | Apparently *ca* 1⅓ | Anterior fourth | No spots (and apparently no bars) | .. | Head ended by a broad trifid spine in centre, and a sharp spine on each side |
| *S. depressiuscula* Macleay | 19+*ca* 66 | 49 | Striated but scarcely ridged | > 2 | > 2 | Anterior third | Two longitudinal rows of small dark-brown or black spots along back | Slightly longer than trunk | Prominent tubercle on each side of snout in front of eyes |
| *S. gracilis* Macleay | 20 (1) + 56 | 58 | .. | 2 | 2 | Middle | Brown cross bars on junctions of annuli, most distinct on back: broad brown band between these, and on eyes | .. | Scarcely depressed |
| *S. argus* Richardson, as interpreted by Waite and Hale, 1921 | 18–22 (17) + 78–90 (68)(3) | 43–50 (55) (2) | Feeble ridge in young examples | > 2 | 1.7–2.8 | About middle [Subdorsal annuli 9–10 (7) + 8–10 (12)] | Male: numerous black white-edged spots: female, often with additional narrow whitish bars (4). | .. | Male depressed; female rather more depressed: supraorbital ridges not continued behind eyes |
| *S. argus* var *brevicaudata* Lucas | 20 + *ca* 60 | 49 or 50 | .. | 2.1 | 1.9 | .. | Dorsal spots black without white edges; in 6 longitudinal rows | .. | .. |
| Chimney Corner specimen | 21 + 69 | 58 | Strong distinct ridge to within last 0.5 mm. of opercle | 2.2 | 2.0 | About middle [Subdorsal annuli 10.8 + 11.2] | Black non-annulated spots in 2 longitudinal rows on dorsum of trunk and tail, mostly 2 spots, anteriorly 4, to each body annulus | .. | No spines or prominent tubercles on head: supraorbital ridges continued behind eyes |

In entries in which annuli-ranges include both unbracked and bracketed values the former are the extremes found by Waite and Hale (1921) and the latter represent extremes found by Waite and Hope (1921) and the latter represent extensions, by express or deficit, of that range as reported by other authors.

(1) Appears in Johnston's second list (1891) as 30.

(2) Should be 58.

(3) Should be 56.

(4) Description greatly condensed.

Waite & Hale attached sufficient importance to the opercular keel to use its presence or absence as a key-character (*S. nigra* 'an opercular keel'; *S. argus* 'no opercular keel in adult'): it has been employed in keys also by Waite (1923), Scott (1939) and others. In the present specimen—which with a length of 280·5 exceeds largest of Waite & Hale's 'many specimens' by 30·5, and may be presumed to be adult—a well-defined keel extends, somewhat obliquely, across the whole operculum, being most elevated anteriorly, and lapsing, within the last 0·5 mm, to little more than height of adjacent rugosities. An examination of the posterior end of the body suggested by the low total of caudal annuli reveals no evidence of mutilation: if injury has occurred, healing has been efficient, the melanophore punctulations of the four tail surfaces extending uninteruptedly round the tip. A further discrepancy may be noted. Waite & Hale observe 'the supraorbital ridges commence on the third part of the snout, but do not extend to behind the eyes'. Here these ridges, which begin 8·8 (left), 8·0 (right) in front of eye, border the orbits for 4·2, and pursue a subparallel course for a distance of about 4 well on to occiput.

The specimen may be referred provisionally to *S. argus* Richardson: but the general position regarding that species would appear to be more fluid than is usually recognized. Reference to Table 1 suggests, for example, that if any reliance can be placed on Castlenau's account of his *S. unicolor*, from Western Australia, this pipefish can hardly be conspecific with Richardson's species.

*Principal dimensions of Chimney Corner specimen.*—*Lt* 280·5. Length to origin of pectoral 47·1, of dorsal 90·5; to termination of adpressed pectoral 51·7, of dorsal base 160·5; to vent 123·5. Head 45·6, snout 31·5, eye 4·2, interorbital 2·4. Depth (and in parentheses width) at middle of snout 2·3 (2·6), front of eye 4·1 (4·8), opercular margin 5·1 (4·1), vent 5·1 (7·0); maximum 6·4 (8·5), occurring at 19th (14th) annulus, about 115 (105) behind tip of snout.

## Family LAMPRIDAE

The family contains a single genus, *Lamprius* Retzius, 1799: the several forms described from various parts of the world are probably conspecific.

## Genus Lamprius Retzius, 1799

**Lampris regius** (Bonnaterre), 1788

*Pleuronectes regius* Bonnaterre, 1788, Tabl. Encycl. Meth., Ichth.: 79. Type locality: 'L'Ocean' (Duhamel) = France.

*Zeus guttatus* Brünnich, 1788, Nye. Saml. K. Danske. Skrift., III: 403.

*Zeus luna* Gmelin, 1789, Syst. Nat. (Linné), ed. 13, 1: 1225. Type locality: 'In mari Normanniam' (Duhamel).

*Lampris regius* (Bonnaterre): McCulloch, 1929, *Mem. Aust. Mus.* V., 1: 137.

*Tasmanian records.*—Australian records of the opah, moonfish, or mariposa are few, a survey by Whitley (1950) listing 5 (Western Australia 1, Victoria 2, Tasmania 2): there are, however, 10 entries for New Zealand in the period 1882-1950. It is clear that this pelagic fish, though widely distributed, is rare (or, at any rate, rarely encountered) in the southern hemisphere: Smith (1950: 141) states it has been obtained only twice in Southern Africa, and it has not been recorded from Ceylon (Munro, 1955). The earliest Tasmanian (and first Australian) specimen was found washed up on the beach near Port Arthur in December, 1895: it measured 3 feet 7 inches [1092] in length to middle of caudal, or 3 feet 6 inches [1067] to caudal base, and weighed 120 lbs. (Morton, 1897). [Lord & Scott (1924), who state that the specimen is preserved in the Tasmanian Museum, Hobart, and that a coloured drawing accompanies entry in register, give weight as an improbable 29 lbs.]. Morton's account includes some dozen measurements and several other observations: a photograph found among R. M. Johnston's memoranda has been published by Whitley (1929 *a*). No details are available to supplement Whitley's second Tasmanian entry: '1936. Storm Bay between Bruny Island and Tasman Peninsula, Tasmania. About 4 feet. *Advocate* 2/12/1936'. Some observations are here given on a third local example, a female, *Ls* 1001, *Lt* 1056, weight approx. 100 lbs., found washed up at Bridport, Dorset, by Mr E. Barnett in August, 1943.

*Fin formulae; general dimensions.*—D. 51 (bases of first eight rays, constituting an elevated section, occupy 60; bases of next eight, 100: rays 1st-9th, 51st 268, 267, 245, 235, 203, 160, 110, 90, 65, 25 long). A. 40 (1st ray 60; longest, 21st, 80; shortest, 40th, 20: last half dozen rays flatter, shorter, more deeply cleft than rest). P. 244 (longest ray 303: fin base 80: depression into which pectoral base fits 110 by 65). V. 14 (longest, 1st and 2nd, 320; shortest, 14th, 35: all cleft, except 1st: fin base 65). C. about 20 main rays + $\frac{7\text{-}8}{10}$ (outermost rays subequal, 255; middle about 70: row of scales along each ray continuous nearly to distal end: spread of fin 400).

Head 320 (to preopercular margin 254). Eye, orbit: horizontal diameter 82, 102; vertical 93, 110. Snout 90. Lower jaw exceeds upper by 17. Height of dorsal profile above a line joining angle of mouth and middle of caudal peduncle (in parentheses depth of ventral profile below this line): at front of eye 100 (180), back of eye 160 (315), end of head 205 (385), pectoral origin 210 (410), dorsal origin 260 (—), dorsal termination 40 (—), anterior margin of vent — (375), anal origin — (370), anal termination — (45). Maximum thickness 180 (at head). Caudal peduncle: minimum depth 70; maximum thickness 50. Nearest approach of lateral line to dorsal profile at level of pectoral. Length to origin of (in parentheses to termination of) pectoral 361 (—), dorsal 469 (958), pelvic 472 (—), anal 661 (962). Vent: length to anterior, posterior margin 600, 647. *Ls* 1001, *Lt* 1056.

*Coloration.*—In advance of level of hind end of pectoral base chiefly silvery (near dorsal and ventral profiles patches of salmon pink: abraded here); behind this, pinkish purple, noticeably darker above lateral line: the whole liberally sprinkled with white spots (modal size 12-15 by

7-10), least abundant between eye and dorsal base. Large dark purple spot about equidistant from dorsal and ventral profiles at level of vent. Dorsal membrane bright pinkish throughout: first 8 rays chiefly pinkish, becoming purplish proximally, tipped with cream distally; other rays whitish: elevated portion of fin with, remainder without, white spots. Anal: membrane red, rays whitish. Pectoral: tips of all rays and distal one-third of membrane cream; rest of fin pinkish, except basal 25 or so of first ray, which is rich red; no white spots. Pelvic: proximal half pinkish red, distal half purplish; scattered white spots over whole fin.

*Remarks.*—Accounts of European examples speak of their brilliant blues, greens and reds: of these colours the third only was exhibited by our specimen; but it may well be that the dark pinkish purple occurring throughout most of the length above the lateral line was blue in life, as in the fish illustrated by Smith (pl. 8, fig. 262).

In gross form our specimen is in tolerably good agreement with most of the available illustrations in general works. From photograph of 1895 specimen (Whitley, 1929 *a*), from outline figure given by Lord & Scott (and from some other figures) it differs principally (i) in higher insertion of pectoral, base of fin being on, instead of below, a line joining middle of eye and middle of caudal peduncle; (ii) in steeper postanal ventral profile (probably an age characteristic), and longer anal base (equal to, instead of two-thirds of, base of non-elevated section of dorsal); (iii) in shape of hindmost portions of dorsal and anal fins, in which lengths of rays successively decrease, instead of increase (in some illustrations remain virtually constant) caudad (in dorsal last 8 measure 60, 55, 50, 40, 33, 30, 27, 25, in anal 49, 45, 42, 35, 28, 25, 22, 20). From Smith's coloured plate it departs noticeably (i) in more anterior insertion of pelvic (below, instead of far behind, dorsal origin); (ii) in much more extensive, and differently disposed, anal base; (iii) in having hindmost point on preopercudum at level of eye, instead of at the angle of the bone, and in having inferior border of preoperculum and operculum relatively closer to orbit.

## Family APLODACTYLIDAE

Of the five members of the family enumerated in the Check List, representing three genera, one only is recorded from Tasmania.

## Genus Dactylosargus Gill, 1862

### Dactylosargus arctidens (Richardson), 1839

*Aplodactylus arctidens* Richardson 1839, Proc. Zool. *Soc. Lond.*, VII: 96. Type locality: Port Arthur [Pembroke], Tasmania.

[?] *Aplodactylus meandratus* Richardson, 1842, *Trans. Zool. Soc. Lond.*, III: 83 (*ex Sciaena meandrata* Solander MS). Type locality: Cape Kidnappers, New Zealand.

*Haplodactylus arctidens* Richardson. Günther, 1858, *Cat. Fish. Brit. Mus.*, I: 81. Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.*, 1882: 111,

[?] *Haplodactylus donaldii* Haast, 1873, *Trans. N.Z. Inst.*, V: 272, pl. XVI, uppermost fig. Type locality: New Zealand ['probably Lyttleton'; McCulloch (1939)].

*Dactylosargus arctidens* (Richardson). Gill, 1863, *Proc. Acad. Nat. Sci. Philad.*, XIV: 40. Waite, 1924, *Rec. S. Aust. Mus.*, II, 4: 480, pl. XXIX, text fig. 379. McCulloch, 1929, *Mem. Aust. Mus.*, V, ii: 256.

*Haplodactylus meandratus* (Richardson). Klunzinger, 1872, *Arch. fur Naturg.*, XXXVIII: 22.

*Dactylopagrus arctidens* (Richardson). Lord & Scott, 1924, Synop. Vert. Anim. Tasm.: 68.

*Distribution and local records.*—The Check List gives Tasmania only: however, it may well be that, as Waite (1924) has plausibly suggested, Klunzinger's Victorian fish is referable to the present species. If such is the case, the distribution covers three States, a record for South Australia having been given by Waite. Waite observes the species does not appear to have been recorded in Tasmania from any source other than the type locality: Lord & Scott (1924), however, comment, 'common in many places, such as Maria Island amid the kelp, from two to five fathoms, and amid the kelp beds of the Derwent Estuary'. On 26th August, 1956, I obtained a specimen, *Ls* 460, *Lt* 549, caught near the shore at Bicheno, Glamorgan: on 6th February, 1957, the Queen Victoria Museum, Launceston, received an example, *Ls* 350, *Lt* 410, secured by Mr T. Williams at Devonport, Devon (Q.V.M. Reg. No. 1957·5·5).

*General observations.*—Waite's description and plate of his specimen, 385 long, from an unidentified locality in South Australia, afford the best available specification of this species. Our material extends the range of the metrical characters recorded by him as follows. Head 4·7 (Devonport), 4·2 (South Australia), 4·3 (Bicheno); depth 3·4, 3·5, 3·2; length of caudal 5·8, 5·5, 5·2, in*Ls*. Eye 5·7, 5'8, 6'5; interorbital 3·2, 3·8, 4·0; snout 3·0, 3·3, 3·1, depth of caudal peduncle 2·1, 'twice', 1·8; longest (4th, 4th and 5th, 4th) dorsal spine 1·8, 1·7, 2·0; longest (2nd, 2nd, 2nd) anal ray 1·5, 1·3, 1·6, in head. Line lat. 105 (61 before vent), 103, 108 (64 before vent): L. tr. thus: 20/*ca* 70, 20/76, -/-. The noticeable irregularity in the course of the lateral line as depicted by Waite is not attributable to imperfect drawing, but represents a genuine characteristic of the fish. The Devonport specimen has one fewer anal ray than the South Australian. Some important dimensions, not recorded by Waite, are here given for the Tasmanian examples, expressed as thousandths of standard length. Length to origin of; termination, of first dorsal 257, 235; 585, 574: second dorsal 617, 612; 860, 843: anal 709, 696; 800, 774: pectoral 180, 179; (adpressed) 420, 397: pelvic 291, 296; (adpressed) 480, 471.

*Differences.*—Our material exhibits the following differences from the South Australian specimen as described and figured by Waite. (i) Waite mentions that bases of first dorsal and anal are each set in a scaly sheath (found also in our examples), but makes no mention of, and fails to figure, any sheath at base of second dorsal. In the Tasmanian specimens the whole length of the second dorsal also is enclosed in a conspicuous sheath, best

developed in the anterior two-thirds of the fin base, where its maximum height somewhat exceeds that of sheath of first dorsal. Closely set scalelets extend up dorsal rays for 0·2 (anteriorly) - 0·6 (posteriorly) of ray length. (ii) Small scales noted as being developed 'along the proximal portions' of caudal rays extend in our examples from 0·7 (medially) to 0·9 (externally) of length of ray. (iii) Waite describes, and figures, pectoral as obtusely pointed, with 7th split ray the longest. Our specimens show a very differently shaped fin. The tips of rays 1-6 form a broadly smooth parabolic curve (individual tips separated by minor scalloping not evident in Waite's figure): 7th, 8th, 9th rays project as separate, progressively longer complex tongues, between which are bold excavations: the inferior 6 simple rays are perhaps much as in the South Australian fish (the point cannot be certainly determined from the illustration), the situation as it obtains in the local examples being that the membrane is incised between successive rays by an outwardly concave curve to an extent such that the point of attachment on one ray lies cephalad of the tip of the ray immediately below it by 1-1½ times maximum width of that ray. The lowest branched ray is biramous; those immediately above it are triramous, and are distinctly narrower and flatter (hence 9th ray is to some extent intermediate in character between those flanking it). Of these three differences, (i) perhaps more probably represents a defect in specification rather than an actual morphological difference; (ii) could clearly be an individual variation; (iii) remains, till further comparative data are available, of uncertain significance.

## Family TRICHIURIDAE

Of the six species, representing three genera, recorded in the Check List one only is known from Tasmania.

### Genus **Lepidopus** Garman, 1770

**Lepidopus caudatus** (Euphrasen), 1788

*Trichiurus caudatus* Euphrasen, 1788, *Stock. K. Vet. Acad. Nya. Handl.*, IX: 52, pl. 9, fig. 2.

*Lepidopus caudatus* Euphrasen. Lord & Scott, 1924, Synop. Vert. Anim. Tasm.: 81. McCulloch, 1929, *Mem. Aust. Mus.*, IV, ii: 267.

*Tasmanian records.*—The only Australian States for which records of this widely ranging species are given in the Check List are New South Wales—['a young example taken by the trawlers is the only specimen recorded' (McCulloch, 1927)]—and Tasmania. The first recorded individual in Tasmania was washed ashore at Battery Point, Hobart, Buckingham, in 1875 (Allport, 1876). A specimen, *Lt* 1461, was found by Mr. E. Bennett in shallow water at Little Devil's Elbow, Tamar River, Devon (approximately 27 miles from river mouth), in 1943 (Q.V.M. Reg. No. 1943·78).

*General account of Little Devil's Elbow specimen.*—D.100 (longest ray, 1st, 39; shortest, 100th, 19: but height of fin does not decrease evenly caudad, length of 11th, 21st . . . 91st rays being 28, 31, 33, 32, 23, 28, 23, 29, 31). A. 25 (1st, 11th, 21st, 25th rays 5, 18, 12, 11 long); 1st ray below 77th dorsal: spines small, numerous. P. 12 (2 broad, undivided; 10 divided in distal one-third to one-half: inferior elongated, 1st, 2nd, 3rd, 5th, 7th, 9th, 11th (longest), 12th 50, 50, 50, 55, 68, 86, 93, 90). C. 18-20 principal rays (longest 60, shortest 17): spread of fin 87. Lower jaw exceeds upper by 9. Head 212 (to hind margin of preoperculum 158). Eye: horizontal, vertical, diameter 39, 36. Interorbital: soft, bony 35, 28. Snout 86. Length to anterior, posterior, margin of vent 718, 728. Distance of lateral line from dorsal profile/total depth at: origin of lateral line (top of gill opening) 25/105, end of head 30/112, pectoral origin 30/112, pelvic origin 35/103, anterior border of vent 55/101, anal origin 40/69; at point of maximum depth (*ca* 530 behind snout-tip) 52/114. Depth of caudal peduncle 7. Thickness at: anterior border of orbit 87, posterior border of orbit 43, operculum 42, vent 34, dorsal termination 11, middle of caudal peduncle 8. Length to origin (in parentheses to termination) of dorsal 143 (1368), pectoral 222, pelvic 277, anal 1170 (1373). *Ls* 1410, *Lt* 1461. Two palatine teeth (apparently originally four) in each row. Maxillary to below 0·2 of eye; its distance from eye subequal to its distal width. Uniform silvery.

*Remarks.*—Dorsal origin is usually shown (Günther, 1880; McCulloch, 1927; Smith, 1950) as distinctly caudad of hind margin of preoperculum, or somewhat more than one eye-diameter behind eye: in our specimen fin originates about 10 in advance of preopercular margin, or 0·6 eye-diameter behind eye.

## Family PSEUDAPHRITIDAE

One Australian species only recognized: formerly included in Bovichtidae; *cf.* Scott (1935: 155).

### Genus **Pseudaphritis** Castlenau, 1872

**Pseudaphritis urvillii** (Cuvier & Valenciennes), 1831

[?] *Eleginus bursinus* Cuvier & Valenciennes, 1830, Hist. Nat. Poiss., V: 161. Type locality: Port Jackson, New South Wales (Quoy & Gaimard).

*Aphritis urvillii* Cuvier & Valenciennes, 1831, Hist. Nat. Poiss., VIII: 484, pl. CCXLIII. Type locality not specified [= Tasmania; McCulloch (1929)].

*Pseudaphritis bassii* Castlenau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1: 72. Type locality: Bass Strait.

*Aphritis urvillii* (Cuvier & Valenciennes). Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.*, 1882: 116.

*Uphritis urvillii* (Cuvier & Valenciennes). Johnston, 1891, *Pap. Proc. Roy. Soc. Tasm.*, 1890: 25, 33 (4, 12 of reprint).

*Aphritis bassii* (Castlenau). Ogilby, 1890, Rec. *Aust. Mus.*, I, ii: 68.

*Pseudaphritis urvillii* (Cuvier & Valenciennes). Ogilby, 1898, *Proc. Linn. Soc. N.S.W.*, XXII, iii: 554. Waite, 1923, Fish. S. Aust.: 164, fig. on p. 164. Lord & Scott, 1924, Vert. Anim. Tasm.: 78. McCulloch, 1929, *Mem. Aust. Mus.*, V, iii: 337.

*Character of first dorsal.*—Neither the 1831 figure—for nearly a century the only published illustration; reproduced in various Australian works, *e.g.*, Waite (1923)—nor the improved figure (based on a Tasmanian specimen 215 long) offered by Waite (1924) represents correctly the character of the first dorsal as found in two individuals, (*a*) *Ls* 75·0, *Lt* 89·5, (*b*) *Ls* 80·5, *Lt* 96·0, trapped in The Arm, George's Bay, Cornwall, on 17th January, 1953. As there depicted, first dorsal ends sheerly at its last spine, without posterior connection of that spine by membrane with dorsum; the clear interdorsal exceeding length of last dorsal spine, and being equal to about two-thirds of first dorsal base. In both our examples the first dorsal (but no other vertical fin) is broadly connected behind with body by membrane. In (*b*), of a total fin base of 12·1, 4·0 (which is subequal to eye) lies caudad of last spine: at the same time, the distance from end of membrane to second dorsal ray is found to be equal to spinous dorsal base, while in the illustrations the latter is subequal to distance from end of last spine to second ray. Subsequent examination of a number of specimens from the North Esk (near Launceston, on Cornwall-Dorset border), in which river, after an absence of two or three decades, this species suddenly appeared in abundance in 1957-58, establishes the fact that this postdorsal membrane attachment is a normal feature.

*General observations.*—Other points in which our specimens differ from these illustrations are: (i) in strict lateral view, eye cuts dorsal profile (this circumstance is associated with the characteristic flattening of the top of the skull, from which derives a vernacular name of River Flathead); (ii) lateral line is throughout closer to dorsal profile than in either figure; at level of termination of soft dorsal being 2½, 3 (*cf.* figures, < 2) times as far from ventral as from dorsal profile; (iii) caudad of end of second dorsal lateral line turns downwards. Ogilby (1890: 69) observes upper and hinder margins of maxilla form a right angle; this is generally true, but does not apply to right maxilla of (*b*): 'preopercle entire'; in our specimens delicately crenulated. In our fish, as in that figured by Waite, adpressed pectoral fails to reach level of anal origin.

D. VII + 20; VII + 19. A.11, 21; 11, 22. (former falls below recognised minimum). C. 14 P.18; 17. L.lat. 63; 65 (to hypural joint + 7 - 10 tubules (the anterior on normally formed scales) extending nearly half length of caudal.

## Family SCORPAENIDAE

With *Glyptauchen* Günther, 1860 included in the Scorpaenidae [as in Waite (1923), McCulloch (1927); not McCulloch (1929) (Synancejidae), Whitley (1931) (Glyptauchenidae)] ten members of the family are reported from Tasmania: (*a*) *Scorpaena* Linné, 1758, (1) *S. ergastulorum* Richardson, 1842 [appears in local list of Lord & Scott as *S. cruenta* Richardson, 1842: see Scott (1942 *b*)], (2) *S. cardinalis* Richardson, 1842; (*b*) *Helicolenus* Goode & Bean, 1895, (3) *H. papillosus* (Bloch & Schneider), 1801 (*c*) *Neosebastes* Guichenot 1867, (4) *N. scorpaenoides* Guichenot, 1867, (5) *N. panda* (Richardson), 1842; (6) *N. thetidis* (Waite), 1899, (7) *N. nigropunctatus* McCulloch, 1915; (*d*) *Centropogon* Günther, 1860, (8) *C. australis* (White), 1790; (*e*) *Gymnapistes* Swainson, 1839, (9) *G. marmorata* (Cuvier & Valenciennes), 1829; (*f*) *Glyptauchen* Günther, 1860, (10) *G. panduratus* (Richardson), 1850.

Of these, (4), (6), 7), (8) are not accredited to Tasmania in the Check List. For (4) see Lord & Scott (1924: 84); for (6) see Scott (1942: 51). No. (8) is not given by Johnston (1891), and apart from the reports of Lord (1922: 71) and Lord & Scott (1924: 85) it has not been recorded south of New South Wales: confirmation of its occurrence in this State would seem to be desirable [especially as confusion has arisen elsewhere between this species and (9)].

Names used in the Check List have for convenience been retained in the key: however, Whitley regards the eastern Australian form of *Glyptauchen* which has in general been regarded as monotypic, as specifically distinct from the typical *G. panduratus* from Western Australia (type locality, King George's Sound), and has described it under the name of *G. insidiator*, with a Tasmanian subspecies *G. i. mirandus*.

## KEY TO SCORPAENIDAE RECORDED FROM TASMANIA

A. Body wholly or largely scaly.

B. Dorsal spines < 15 (12-13). Length > 200 (modally 250-450).

C. Dorsal spines 12. Base of 2nd dorsal > ½ base of 1st dorsal.

D. Bony stay of cheek with several spines (2 spines from preorbital overhanging maxillary). Lower part of operculum naked. Pectoral with some rays simple; fin not cut square across upper rays.

E. Scales in a row beneath lateral line ≤ 45. Longest dorsal spine > ½ head. 11th dorsal spine > ½ 12th .... .... .... .... .... .... .... *Scorpaena cruenta*

EE. Scales in a row beneath lateral line > 45 (50-60). Longest dorsal spine ≤ ½ head. 11th dorsal spine < ½ 12th .... .... .... *Scorpaena cardinalis*

DD. Bony stay of cheek without spines. Lower part of operculum scaly. Pectoral with 8 lower rays simple; fin cut square across upper rays .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... *Helicolenus papillosus*

CC. Dorsal spines 13. Base of 2nd dorsal < ½ base of 1st dorsal.

F. Deep naked groove on nape. Adpressed pectoral reaches about to level of anal termination. Base of 2nd dorsal ≐ 2 length of caudal peduncle. L.lat. > 50 (≐ 58) .... *Neosebastes panda*

FF. No deep naked groove on nape. Adpressed pectoral reaches, or fails to reach, level of anal origin. Base of 2nd dorsal < 2 (≐ 1) length of caudal peduncle. L.lat. < 50.

G. L.lat. > 40 (≐ 48). 2nd dorsal spine > 3rd Pectoral satisfies 2 conditions: ray tips form even curve; no incision of membrane between adjoining lower rays .... *Neosebastes scorpaenoides*

GG. L.lat. < 40 (35-38). 2nd dorsal spine < 3rd Pectoral does not satisfy both the specified conditions.

H. Curve formed by ray tips of pectoral even: incision of membrane between adjoining lower rays considerable. 12th dorsal spine > ½ 1st dorsal spine. Membrane from 2nd dorsal spine attached to 3rd below middle of latter. Body with several large black blotches; not with numerous small black dots. L.lat. 38 .... *Neosebastes thetidis*

HH. Curve formed by ray tips of pectoral sharply embayed near middle: incision of membrane between adjoining rays slight. 12th dorsal spine < ½ 1st dorsal spine. Membrane from 2nd dorsal spine attached to 3rd above middle of latter. Body without large black blotches (may have indistinct brown blotches); with numerous small black dots. L.lat. 35 .... *Neosebastes nigropunctatus*

BB. Dorsal spines ⩾ 15 (15-17). Length < 200 (modally 150).

I. A broad deep hollow on nape. Dorsal begins behind posterior border of eye (by ⩾ length of 1st dorsal spine). 2nd dorsal spine < (≐ 2/3 of) 7th dorsal spine. Anal base > (2-3 times) length of caudal peduncle. Dorsal spines 17 .... *Glyptauchen panduratus*

II. No broad deep hollow on nape. Dorsal begins at posterior border of eye. 2nd dorsal spine > (≐ 1½ times) 7th dorsal spine. Anal base ⩽ length of caudal peduncle. Dorsal spines 15-16 .... *Centropogon australis*

AA. Body scaleless .... *Gymnapistes marmorata*

## Genus Gymnapistes Swainson, 1839

**Gmnapistes marmorata** (Cuvier & Valenciennes), 1829.

*Apistus marmoratus* Cuvier & Valenciennes, 1829, Hist. Nat. Poiss., IV: 416. Type locality: 'Timor' (Péron). [Check List suggests 'probably = West Australia'].

*Apistus tasmaniensis* Gray, 1838, *Ann. Mag. Nat. Hist.*, I: 111. Type locality: Van Diemen's Land (Gunn).

*Pentaroge marmorata* (Cuvier & Valenciennes). Günther, 1860, Cat. Fish. Brit. Mus., II: 132. Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.*, 1882: 115. McCulloch, 1915, Biol. Res. Endeavour, III, 3: 161, pl. XXXVI, fig. 2. Lord 1923, *Pap. Proc. Roy. Soc. Tasm.*, 1922: :71. Lord & Scott, 1929, Synop. Vert. Anim. Tasm.: 85.

*Gymnapistes marmorata* (Cuvier & Valenciennes). McCulloch, 1929, *Mem. Aust. Mus.*, V, iii: 338.

*Material.*—This widely spread Australian (Australasian ?) naked species—which has often been involved in confusion with the ecologically and morphologically similar scaled *Centropogon australis*s see, *e.g.*, McCulloch (1915, 1927), Waite (1923)—has had a long local history, with Tasmania figuring as type locality of Gray's synonymic *G. tasmaniensis*: listed—*fide* Johnston (1883)—in Allport MS. The present observations are based on two specimens trapped in The Arm, George's Bay, Cornwall, on 18th January, 1953: (*a*) *Ls* 101·3, *Lt* 122·0; (*b*) *Ls* 105·5, *Lt* 130·0 (clearly of same year class: *V* for *Ls*, *Lt* 2·0, 3·2).

*Variation.*—The standard figure is that by McCulloch (1915, pl. XXXVI, fig. 2), based on an individual 137 long from Swan River, Western Australia. Comparison of our material with this illustration and with various descriptions reveals the following differences. (i) The spinous dorsal is usually said to range from (and is by McCulloch expressly limited to) XII to XIII, with the rayed constant at 10: specimen *a*, with XII, 10 conforms to these specifications, but *b*, with XI, 9, falls below admitted minimum for both parts of fin (and, in respect of spine-number, actually transgresses the generic limit). (ii) In *b* the first anal ray, like the last, is split almost to base, giving a ray total, on the usual conventions, of 5 only, instead of the normal 6. (iii) The generic character of union of pelvic with body by a fold of membrane is indicated in McCullochs figure, but the extent of the junction as there shown is quite insignificant in comparison with that found in our specimens, in which the fold is traceable caudad of tip of adpressed fin. its line of attachment extending behind base of 5th pelvic ray by 21, 20. (iv) Both dorsal and anal are much more broadly connected by membrane to peduncle than in the illustration, termination of anal membrane occurring caudad of last anal ray by 18·5, 14, a distance exceeding interval between first and last anal rays. (v) The cephalic spines, which are known to be variable in size, are much longer in our material than in McCulloch's, preorbital extending beyond eye, preopercular to level of pectoral origin. (vi) Length of 2nd anal slightly exceeds length of pelvic spine, and is somewhat greater than (figure, about 0·9 of) height

of erected dorsal: with anal lowered, spine extends caudad of base of last ray by a distance subequal to width of free end of maxilla. (vii) Longest dorsal spine is 4th (figure, 3rd), its length exceeding (figure, 3rd about 0·9 of) combined eye and snout. These differences (of which (vii) is most likely to be of systematic significance) are certainly not of specific value: as possible pointers to subspecific differentiation their significance could be determined only by examination of further material from both sources.

*General features.*—At middle of caudal peduncle lateral line is (*a*) a little nearer to, or (*b*) much further from, dorsal than ventral profile. Beyond hypural it turns rather abruptly (but even in same specimen to a variable extent) upwards, continuing with one or two tubules on to fin base. Tubules total 30, 29, of which 12-13 are preanal. Mandibular tooth band almost constant in width through anterior two-thirds of length, thereafter narrowing to a point: at symphysis bands contiguous internally only. Bands in upper jaws narrowing evenly backwards; separated anteriorly by a distance subequal to anterior width of band. Palatine band similar to premaxillary band, but about one-third shorter and narrower. Vomerine teeth a subtriangular patch in *a*, a ∧-shaped set in *b*. Gill-rakers on lower limb of anterior arch 9; lobate, anteroposteriorly compressed in middle, more mound-like at ends, of series; inferior ones delicately spinigerous. From base of main preopercular spine (below which, along preopercular border, are four small spines, progressively less pungent inferiorly) conspicuous ridge extending forward to lowest point of orbit. A pair of prone supranarial spines, slightly convergent posteriorly. Median interobital groove deeper, at its middle narrower, than curved lateral grooves.

*Coloration.*—McCulloch (1915: 161) observes the markings 'differ very much in the different specimens from various localities, both in form and intensity, though their disposition is much the same in all; in some the larger dark blotches are brown, and surounded by more or less abundant marking, whilst in others they are deep black on a plain white ground'. Neither this, Macleay's (1880) 'dirty yellowish, largely marbled with brown', Waite's (1923) 'greyish yellow marbled with brown' nor any of the more familiar accounts conveys the slightest idea of the variety of the richness of the colours in life. The mosaic character and the irregularity in location and extent of the minor pattern elements are such as to render impracticable their specification in the space here available: as some indication of their mere diversity, however, it may be recorded that the George's Bay specimens exhibited, among others, the following features: ground colours of pale and medium grey, greenish grey, green, greenish gold, flesh, flesh tinted with gold, pure white (belly), dark greenish (occiput), silver faintly gilded; mottlings on head and body of warm brown (some patches with darker edges, some golden peripherally), blackish, golden brown, gold, reddish, green, green somewhat silvered, olivaceous, pink; line of rich purple (above upper lip in *a*); fin membranes greyish, white, greenish, pale greenish tinged with red, reddish, dusky, pinkish fawn, hyaline; markings on fins cloudings or patches of blackish, golden brown, reddish brown, pale orange, iridescent green (small patches on pectoral of *a*), two pale violet markings simulating hypurals (base of caudal of *a*), bars of blackish, imperfect bars of green (across caudal of *a*).

*Behaviour.*—The fish were caught in a wire trap, the diameter of the mouth of which barely exceeded one inch. It is not easy to see how they effected their entry, their maximum depths with dorsals erect being 48·5, and with dorsals lowered 31, 32·5. One individual obstinately refused for a considerable time to enter a jar the internal diameter of the mouth of which of which was 52·5. When observed in the trap, both specimens had the cephalic spines erected, the axis of the preorbital dagger being almost normal to cheek: at death spines reclined against head. While the fish were being extricated from the trap, the spines became entangled several times in the wire netting.

*Vernacular name.*—Lord & Scott, in agreement with Johnston (1891), head their account of this species 'Soldier (of Tasmania)', and call attention to the use in South Australia of the term 'Cobbler'. I found the name in familiar use among boys at St Helens was Cobbler.

## Family ALUTERIDAE

Of the forty-eight Australian species set out in the Check List twelve, representing two genera, are credited to Tasmania: (*a*) *Meuschenia* Whitley, 1929, (1) *M. hippocrepis* (Quoy & Gaimard), 1824; (2) *M. convexirostris* (Günther), 1870; (3) *M. trachylepis* (Günther), 1870; (4) *M. maculosa* (Richardson), 1840 [type locality, Port Arthur (Pembroke) Tasmania]; (*b*) *Cantherhines* Swainson, 1839; (5) *G. güntheri* (Macleay), 1881; (6) *C. brownii* (Richardson), 1846; (7) *C. spilomelanurus* (Quoy & Gaimard), 1824 [the synonymic *Aluterius paragaudatus* Richardson, 1846 has Port Arthur, Tasmania and Port Jackson, New South Wales as type localities]; (8) *C. granulatus* (White), 1790; (9) *C. australis* (Donovan), 1824 [type locality, Van Diemen's Land: the synonymic *Monacanthus rudis* Richardson, 1844 has Port Arthur, Tasmania as type locality]; (10) *C. melas* (Günther), 1876 [Tasmania (Allport): endemic]; (11) *C. peroni* (Hollard), 1854 [type locality, 'Des terres australes' (Péron): Check List comments 'probably Tasmania']; (12) *C. gunnii* (Günther), 1870 [type locality, Tasmania: endemic]: also one species of *Aluterus* Cloquet, 1816, (13) *A. monoceros* (Linné), 1758, is recorded (*fide* Schmeltz) from Bass Strait.

Lord & Scott (1924) omit (3), (6), (8), [and (13], listing (9) as *Cantherines rudis*: they add (14) *C. mosaicus* (Ramsay & Ogilby), 1886 and one species of *Brachaluteres* Bleeker, 1866, (15) *B. trossulus* (Richardson), 1846. No specific records are given by these authors.

Records are given below of (16) *C. setosus* (Waite), 1899, a formal addition to the local list.

Since the appearance of the Check List most of our leatherjackets have been relegated to other genera of later or earlier date. In the key I have accepted generic attributions adopted in the synopsis by Fraser-Brunner (1941). This refers (1),

(2), (9), (10), (16) to *Navodon* Whitley, 1930; (4) (not noticed by Fraser-Brunner), (5), (6), (7), (11), (12) to *Acanthaluteres* Bleeker, 1866; (8) to *Scobinichthys* Whitley, 1931; (14) to *Eubalichthys* Whitley, 1930: (3), (15) remain in *Meuschenia, Brachaluteres,* respectively; while on the vexed question (Whitley, 1929: 141) of the origin and form of the generic name for (13) (in Check List attributed to Cloquet, 1816 as *Aluterus*), Fraser-Brunner adopts *Alutera* (Cuvier) Oken, 1817. However, it should be observed that *Navodon* as thus defined by Fraser-Brunner is decidedly wider in scope than envisaged by its founder, and in at least one feature ('caudal spines often present' in subgenus *Navodon*) is in direct conflict with the original diagnosis ('no spines or bristles on caudal peduncle').

When providing synopses of the New South Wales and South Australian leatherjackets both McCulloch (1927) and Waite (1923) found it necessary to omit various imperfectly characterized species described last century. The restricted character of such diagnoses certainly poses difficulties for the keymaker: at times, even generic attributions may be uncertain—thus Whitley (1929) considers it probable (4) belongs to his genus *Meuschenia* (with spines on side of tail), while McCulloch (1927) suggests it may be merely a sexual form of (7), a species lacking such spines. In the key set out below an attempt has been made to cope with the position as fully as is practicable by entering two species for which basic data is wanting each at two points: it should be borne in mind, however, that the whole identificatory apparatus necessarily remains, at least in respect of some early species, at best somewhat provisional.

## Key to Aluteridae Recorded from Tasmania; and *Aluterus monoceros* (Linné) Recorded from Bass Strait

Dorsal fin formula records rays only: 'dorsal spine' means sole, or main, dorsal spine. In specific diagnoses the following items are regularly given in sequence [N.D., no data available: any additional special data given in parentheses at end]. Number of dorsal rays. Number of anal rays. Dorsal spine: shape; insertion relative to eye; length. Upper profile of snout. Location of gill opening relative to eye. Nature of pubic spine. Coloration. Modal standard length.

(Two species of uncertain affinity appear twice in key: see text).

A. Dorsal rays $>$ 45. Anal rays $>$ 45.

46-48. 48-53. Proconvex; before middle; 2-3 in snout. Half, or more, in advance of anterior border. No spine. Brown or black; fins yellow. 375. (Dorsal spine weak, without barbs: gill opening more nearly horizontal than vertical) .... .... *Aluterus monoceros*

AA. Dorsal rays $<$ 45. Anal rays $<$ 45.

B. Pubic bone without terminal spine or spines. Dorsal spines without rows of barbs; normally with flexible bristles. Dorsal and anal rays together $<$ 56. *Ls* modally $<$ 100.

24-28. 22-26. Proconvex; before middle; $=$ snout. Partly concave or straight. Wholly, or mainly, behind posterior border. No spine. Dark green; with darker specks, and blue or white markings that tend to form line (or lines) along ventral contour. 90 .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... *Brachaluteres trossulus*

BB. Pubic spine with terminal spine or spines (may be hidden below skin). Dorsal spine with rows (2 or 4) of barbs; normally without flexible bristles. Dorsal and anal rays together $>$ 56. *Ls* modally $>$ 100.

C. Depth at origin of second dorsal $\geqslant$ *Ls*; $=$ distance from tip of snout to origin of second dorsal. Distance between first rays of dorsal and anal $>$ 4 distance between last rays of these fins. Colour pattern (which may become obscure or lost in adult) including contiguous hexagonal markings of blue.

35-36. 32-34. Proconvex; at or in advance of middle; 1½ in snout. Concave or straight. Below. Very small, with a few spinules. Reddish or yellowish; with blue wavy lines, some joined to form contiguous hexagons, which often include brown blotch (markings may be lost in adult). 460 .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... .... *Eubalichthys mosaicus*

CC. Depth at origin of second dorsal $<$ ½ *Ls;* $<$ (usually 1½-2 in) distance from tip of snout to origin of second dorsal. Distance between first rays of dorsal and anal $<$ 4 (usually 2-3) distance between last rays of these fins. Colour pattern not including contiguous hexagonal markings of blue.

D. Spines (larger than ordinary spines on scales) present on sides of tail (bristles also may be present).

E. Dorsal rays $\leqslant$ 33. Anal rays $\leqslant$ 31. Dorsal spine four-edged, edges equidistant, each with barbs.

F. Colour pattern including blue dots.

32-33. 30-31. Straight; behind middle; 1½ in snout. Convex. Partly in advance of anterior border. Not visible, or very small. Greenish; blue dots on tail and posterior part of trunk,

oblique and longitudinal lines on head and anterior part of trunk. 300. (Adult with two pairs of strong straight conical spines, and some short bristles, on each side of tail) .... .... .... .... .... .... .... .... .... .... .... .... .... *Acanthaluteres brownii*

FF. Colour pattern not including blue dots.

29-33. 29-30. Two linear segments at obtuse angle; proximal being half distal, or less; behind middle; $1\frac{3}{4}$ in snout. Straight or concave. Below. Very small, very feebly armed. Brownish or greenish with darker spots; caudal with one or two dark cross-bars. 150. (Caudal pointed). *See also* MM .... .... .... .... .... .... .... .... .... .... .... .... .... .... *Acanthaluteres maculosus*

EE. Dorsal rays > 33. Anal rays > 31. Dorsal spine not four-edged; anterior series of spines smaller, and decidedly closer together, than posterior series.

G. Colour pattern including blue lines and/or blue spots.

H. Two pairs of spines on each side of tail. Giill opening below, or partly below and partly behind, eye. Spinules on skin in groups of 2-5.

36-39. 33-35. Nearly straight; above middle; 1 1/5 in head. Straight. From middle to, or beyond, posterior border. Very small, with short radial spikes. Brownish or blackish; blue spots along bases of dorsal, anal, caudal; vertical fins yellow or orange. 200. (Spines on tail strong, compressed, bent forward) .... .... .... .... .... *Meuschenia trachylepis*

HH. Three (sometimes two) pairs of spines on each side of tail. Gill opening partly in advance of eye. Spinules on skin not in groups, equidistant.

35-39. 33-37. Proconvex; behind middle; $1\frac{3}{4}$-2 in head. Convex. To, or in advance of, anterior border. Evident. Olive green above, lighter below, blue lines and spots; typically, horseshoe-haped blackish markings in yellow patch behind pectoral. 460 .... .... .... .... .... .... *Navodon hippocrepis*

GG. Colour pattern not including blue lines and/or blue spots.

34-37. 32-35. N.D.; behind middle; much shorter than head. Convex. Partly in advance of anterior border. Small, prominent, with barbs. Greyish; uniform, or clouded with darker. 230. (Small spiny, very distinct scales). *See also* PP .... .... .... .... .... .... .... .... .... .... .... .... .... .... *Navodon convexirostris*

DD. No spines (larger than ordinary spines on scales) present on sides of tail (bristles may be present).

I. Four series of barbs on dorsal spine.

J. Dorsal spine four-edged, edges equidistant, each with barbs.

K. Length of caudal peduncle < ($\frac{1}{2}$-$\frac{2}{3}$ of) interdorsal, ⩾ 2 in snout.

L. Colour pattern including blue spots and streaks; no pronounced dark bars across caudal. Dorsal spine long, tapering throughout whole length.

33-35. 32-33. Straight or slightly proconcave, tapering; behind middle; $1\frac{1}{2}$ in snout. Straight or slightly concave. Below. Very short. Brownish yellow; with blue spots and streaks; a blue area, with brown spots and streaks, above anal base. 300. (Toothbrush-like patch of bristles on each side of tail in adult male) .... .... .... .... .... .... .... .... .... *Acanthaluteres güntheri*

LL. Colour pattern not including blue spots or streaks; two or more narrow dark bars across caudal. Dorsal spine short, subequal in diameter throughout most of its length.

32-34. 31-33. Straight; behind middle; 2 in snout. Sigmoid. Below. Prominent, covered with spinules. Yellowish brown; dark brown markings that may form bars; dorsal spine blackish; caudal with two or more dark cross bars. 320. (Toothbrush-like patch of bristles on each side of tail in adult male) .... .... .... .... .... .... .... .... .... .... .... *Acanthaluteres peroni*

KK. Length of caudal peduncle ≐ interdorsal, < 2 (about 1½) in snout.

M. Colour pattern including blue lines. Caudal rounded.
30-32. 28-32. Slightly proconvex behind middle; 2 in snout. Sigmoid. Below. Obsolete. Brownish green; two black-edged blue lines from chin, one through eye, one to pectoral base; dark line from eye to eye, over snout; caudal with dark cross bar. 200. (Large specimens, probably males, with tooth-brush-like patch of bristles on each side of tail) .... .... .... .... .... .... .... .... .... .... *Acanthaluteres spilomelanurus*

MM. Colour pattern not including blue lines. Caudal pointed.
29-33. 29-30. Two linear segments at obtuse angle, proximal half distal, or less; behind middle; 1¾ in snout. Straight or concave. Below. Very small, feebly armed. Brownish or greenish; with darker spots; caudal with one or two dark cross bars. 150. *See also* FF .... .... .... .... .... .... .... .... .... .... .... *Acanthaluteres maculosus*

JJ. Dorsal spine not four-edged; anterior barbs smaller, and if in rows decidedly closer together, than posterior series.

N. Anal rays > 30.

O. Dorsal spine long, < 2 in head, slender. Dorsal profile of snout convex.

P. Anal fin, dorsal spine black. Skin velvety, without distinct scales.
34. 34. N.D.; behind middle; 1½ in head. Very convex. Partly in advance of anterior border. Small. Brownish black; two whitish bars across chin; dorsal spine black; caudal black, other fins light-coloured. 350 .... .... .... .... .... .... *Navodon melas*

PP. Anal fin, dorsal spine not black. Skin with spiny, very distinct scales.
34-37. 32-35. N.D.; behind middle; much shorter than head. Convex. Partly in advance of anterior border. Small, prominent, with barbs. Greyish; uniform, or clouded with darker. 230. *See also* GG .... .... .... .... .... .... *Navodon convexirostris*

OO. Dorsal spine short, > 2 in head, stout. Dorsal profile of snout straight or concave.
34. 33. N.D.; behind middle; N.D. ('strong'). Straight or concave. Largely in advance of anterior border. Small, with spines pointing forward and backward. Dark brown; mottled with black. 275 .... .... .... .... .... .... .... .... .... .... .... .... .... *Acanthaluteres gunnii*

NN. Anal rays < 30.
30. 28-29. Proconvex; at middle; ≥ snout. Concave or sigmoid. To, or beyond, posterior border. Very short. Brownish grey; marbled darker; papillae may be whitish. 225. (Large pubic flap; each scale with one truncate spine) .... .... .... .... .... .... .... .... .... .... .... .... *Scobinichthys granulatus*

II. Two series of barbs on dorsal spine.

Q. Spinules on scales slender, acuminate, mostly curved. Dorsal profile of snout straight or concave. Pubic spine conspicuous.
33-35. 31-36. Proconvex; behind middle; ≐ snout. Straight or concave. Below. Conspicuous, characteristically with 8 spinules. Light greenish; darker cloudy markings on body, rather obscure oblique dark bars from snout, chin, throat, towards eye, dorsal and anal yellow, caudal usually with blackish curved inframarginal bar. 280 .... .... .... *Navodon setosus*

QQ. Spinules on scales stout, obtuse, straight. Dorsal profile of snout convex or straight. Pubic spine inconspicuous.
34-37. 34-36. Proconvex; behind middle; 4/5 snout. Convex or straight. Partly (? wholly, Saville Kent, 1897) behind. Small, 'studded with obtuse grains'. Brown; uniform, or with four indistinct whitish longitudinal bands, caudal with broad blackish margin. 225. (In breeding male, browns and whites replaced by blues and yellows) .... .... .... .... *Navodon australis*

## Genus Navodon Whitley, 1931

### Navodon setosus (Waite), 1899

(Text figure 1)

*Monocanthus setosus* Waite, 1899, *Mem. Aust. Mus.*, IV, i: 91, pl. XVI. Type locality: Off Wollongong, New South Wales; 63-75 fathoms.

*Pseudomonacanthus setosus* (Waite). Waite, 1904, *Mem. N.S.W. Nat. Club*, II: 56.

*Cantherines setosus* (Waite). Waite & McCulloch, 1915, *Trans. Roy. Soc. S. Aust.*, XXXIX: 472, pl. XIV.

*Cantherhines setosus* (Waite). McCulloch, 1929, *Mem. Aust. Mus.*, V, iii: 419.

*Navodon setosus* (Waite). Whitley, 1931, *Rec. Aust. Mus.*, XVIII, 3: 123. Fraser-Brunner, 1941, *Ann. Mag. Nat. Hist.* (11), 8, 45: 185.

*Tasmanian records.*—The only State recognized in the Check List is New South Wales. However, Waite & McCulloch (1915: 473) report examples from *Simplon* stations 2 (Lat. 32° 36′ S., Long., 129° 54′ E.) in 22 fms., and 8 (Lat. 34° 46′ S., Long. 133° 10′ E.) in 72 fms.; from between Port Hacking and Wollongong, New South Wales (50-70 fms.), east of Babel Island, Bass Strait (40-100 fms.), and off the Investigator Group, South Australia (37 fms.): they give the distribution as 'moderately deep water off the southern portion of New South Wales, Victoria, Tasmania, and South Australia'. Specimens from Bass Strait have been noted also by Whitley (1931). The species does not appear in any local list, and there do not seem to be any definite Tasmanian records. I have examined two juveniles (*a*) *Ls* 78·3 (fig. 1A), (*b*) *Ls* 80·5, washed up at Bicheno, Glamorgan, about May, 1955.

Mrs. C. Gray, the owner of these specimens, informs me that at the time they were collected the local beaches were strewn with hundreds of example of comparable size; while fishermen reported the presence of thousands floating on the surface for several miles out from shore. The cause of death is unknown: mass mortality of this sort has been associated elsewhere with various factors, including seismic disturbance, submarine discharge of poisonous gases, and (*e.g.*, Smith, 1959: 8) sudden decrease in temperature (for instance as the outcome of a local upwelling of cold deep water).

*Fin counts; body proportions.*—D. I + 36, I + 30 + (imperfect). A.36, 33. P.15, ?. C.12, 12. Some general proportions, expressed as thousandths of *Ls*, are set out in Table II: no detailed dimensions of this species have hitherto been published.

TABLE II

*Navodon setosus* (Waite), 1899. *Dimensions of Two Tasmanian Specimens from Bicheno, Glamorgan.* Actual measurements in millimetres in first line: all other dimensions expressed as thousandths of standard length.

| Dimension | Specimen *a* | | Specimen *b* | |
|---|---|---|---|---|
| Standard length, total length | 78·3, | 105·1 | 80·5, | imp. |
| Gill opening: length to front, to back | 298, | 331 | 278, | 326 |
| Gill opening: oblique length, direct distance from orbit | 68, | 55 | 85, | 53 |
| Eye: horizontal, vertical, diameter | 109, | 92 | 118, | 89 |
| Eye: direct distance from snout-tip, from second dorsal origin | 234, | 288 | 226, | 302 |
| Snout, interorbital | 223, | 102 | 206, | 86 |
| Posterior nostrils: internarial, direct distance from orbit | 56, | 36 | 58, | 37 |
| Vent: length to, direct distance from tip of pelvic spine | 598, | 151 | 610, | 137 |
| First dorsal: length to origin, to termination | 285, | 363 | 273, | 368 |
| Second dorsal: length to origin, to termination | 608, | 927 | 604, | 916 |
| Anal: length to origin, to termination | 616, | 944 | 591, | 922 |
| Pectoral: length to origin, length of fin | 317, | 155 | 311, | 143 |
| Length of dorsal spine, of longest dorsal ray | 229, | 163 | imp., | 153 |
| Length of longest anal ray, of longest pectoral ray | 153, | 152 | 124, | 125 |
| Length of pubic bone, of exposed pubic spine | 447, | 75 | 398, | 67 |
| Depth: at anterior, posterior, border of eye | 397, | 505 | 374, | 466 |
| Depth: at end of pubic spine, vent | 603, | 473 | 557, | 465 |
| Depth: at termination of second dorsal, caudal peduncle (min.) | 148, | 112 | 152, | 104 |

*Spines on fins.*—These are not mentioned or figured in original account, though some are indicated on caudal rays (but not elsewhere) in Waite & McCulloch's plate. In these juveniles rays of second dorsal bear 4 series, mutually at right angles, of straight, slender, sharp, somewhat upwardly directed barbules, occurring on proximal one-third of most, and three-quarters of some, rays (*a*), or on more than half of most rays (*b*). Modally 16-18 barbules in a series, their length commonly two-thirds of, sometimes equal to, diameter of ray. On anal rays are similar series of barbules; those in plane of membrane extending two-thirds, exceptionally three-quarters, of interray distance; some falcate; up to 24 in a series (fig. 1H). Proximal one-fourth of pectoral rays (up to beginning of flattening) with 4 series of very short spinules. All caudal rays are heavily beset with spinules. On broad face of ray (presented alternately to left and to right of fish in successive caudal rays) each internode in proximal portion of fin bears about 24 rows, each usually of 6 (occasionally 5) spinules; distally, internodes (which, except on outer rays, are twice as long as they are basally) each carry about 8 rows, each usually with 10 (up to 12) spinules—a single ray

being armed with, in all, upwards of two thousand spinules. On 1st, 12th rays, which are unbranched, and basally on narrow faces of some other rays, spinules are less erect than on broad faces of branched rays. Scattered spinules occur also on caudal membrane, particularly proximally. For armature of dorsal spine see figs. 1 C, D, E: for pubic spine see figs. 1 J-M.

*Other additions to original description.*— (i) Waite notes: 'the teeth are damaged. There are three pairs in the lower jaw'. The complement is the family one, namely, in lower jaw 6 in a single series, in upper jaw 6 in an outer, 4 in an inner, series. In our specimens (fig. 1B), of the 3 mandibular pairs, 1st (most anterior) is highest, 2nd broadest, partly overlapped externally by 3rd: in upper jaw, of outer series 1st is longest, 3rd broadest and shortest; of inner series, 1st is represented in buccal view by a cusp, rising from posterior one-third of cutting edge, and having the appearance, on cursory examination, of being a narrow subcylindrical caniniform tooth wedged in between 1st and 2nd teeth of external series, while 2nd inner tooth makes a wider, but less elevated, appearance, without cusp, between 2nd and 3rd outer teeth. Innermost tooth in lower jaw is in contact with 1st and 2nd outer teeth, and 1st inner tooth of upper jaw. (ii) After death the elevated bases of the dorsal and anal may collapse (as in some other leatherjackets) to form a conspicuous furrow, marking the location of the second row of radials; the groove being bounded above and below by conspicuous ridges, of which the superior is constituted by the nodular third peterygiophores and the embracing dilated tips of the proximal ends of the lepidotrichia, while the inferior is the expanded upper end of the first pterygiophores. (iii) Myomeres *ca* 20, of which 6 are preanal. (iv) Pubic spine acts as a mast, to the whole length of which is attached a subtriangular (in dried fish, paper-thin, translucent) flap, narrowing back to vent; crossed by oblique lines constituted by ridges of scales, from which arise spinules, 2-6 on a scale, straighter, distinctly larger here than on most parts of body (fig. 1I). (v) Second dorsal spine (figs. 1 F, G) tumid above, broadly keeled below; with stout, upwardly concave median posterior odontoid process. (vi) In dry specimens upper end of gill opening comes to extend back to, or slightly caudad of, posterior orbital border. (vii) Anal originates below 3rd, 2nd dorsal ray. (viii) Dorsal terminates in advance of anal by 5 rays of latter.

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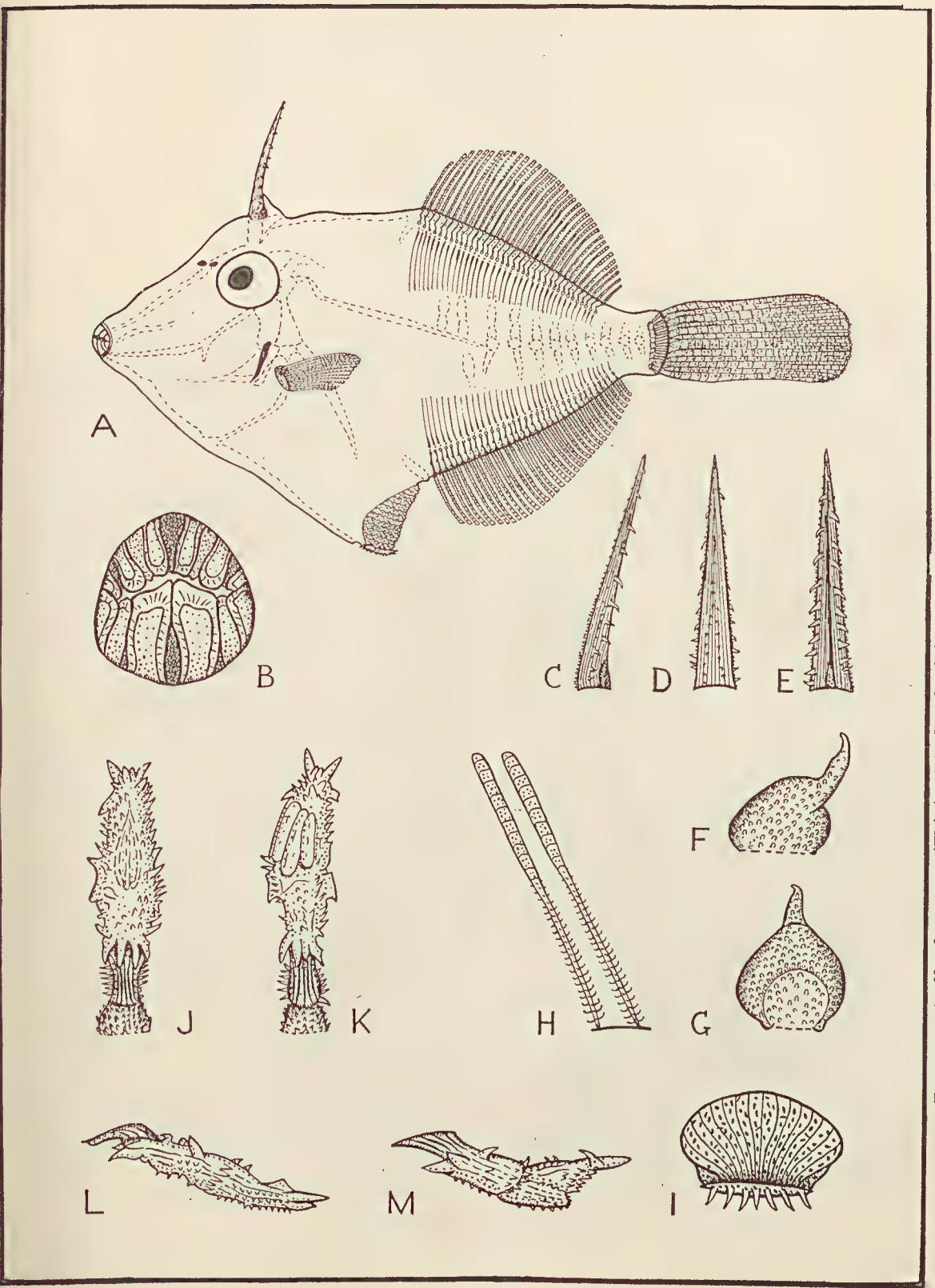


TEXT-FIGURE 1.—*Novodon actosus* (Waite), 1899. Two beach-dried juveniles from Bicheno, Glamorgan, Tasmania: standard length 78·3 (specimen *a*), 80·5 (specimen *b*). A, specimen *a*, × about 1 1/5: only scales indicated are the larger ones on the pubic flap. B, teeth, anterior aspect (reconstruction, based on *a* and *b*); × 7. C, D, E, first dorsal spine, lateral, anterior, posterior aspects (*a*); × 2. F, G, second dorsal spine, lateral, dorsal aspects (*b*); × 12. H, two consecutive anal rays (*b*) × 7. I, scale from pubic flap (*a*); × 14. J. K, pubic spine, lateral aspect (*a*, *b*); × 7. L, , pubic spine, ventral aspect (*a*, *b*); × 6.

# LOWER PALAEOZOIC UNCONFORMITIES IN SOUTH-WESTERN TASMANIA

By

B. SCOTT

*Lyell-E.Z. Explorations**

(With 2 text figures).

## INTRODUCTION

Recent geological work in south-west Tasmania on a regional scale has allowed the compilation of existing information regarding Lower Palaeozoic unconformities, namely the description of new localities and in some cases the amplification and extension of previously described exposures.

Carey and Banks (1954, p. 245) provide a review of information to 1954 and their classification of unconformities has been adopted in this paper. These are repeated here (op. cit. p. 264):

**Tyennan Unconformity.**—The Tyennan Unconformity may be defined as an angular discordance between pre-Dundas rocks below and the Junee Group above as revealed on the south-eastern slope of Tim Shea, at the head of Tyenna Valley. Stratigraphically it may be considered as the erosional surface in pre-Dundas rocks on which the Junee Group was deposited. The orogenic movements occurring within the span of time represented by this unconformity is referred to as the Tyennan Orogeny. This time is a minimum of that during which the Dundas Group was deposited (at least lower Upper Cambrian to upper Middle Cambrian, Opik, 1951*a*, 1951*b*). The base of the Junee Group (Owen type Conglomerate) indicates a Lower Canadian age (Opik, 1951*a*) so that the Tyennan Orogeny must precede this.

**Stichtan Unconformity.**—The Stichtan Unconformity has been defined as the angular discordance between the Carbine Group below and the Dundas Group above as revealed on the western flank of the Sticht Range and its southern continuation to a point east of Lake Dora in the West Coast Range. Stratigraphically the Stichtan Unconformity may be considered as the erosional surface on which the Dundas Group was deposited. It is an expression of orogenic movement of pre-upper Middle Cambrian age, followed by a period of erosion or non-deposition prior to the deposition of the Dundas Group. This movement is referred to as the Stichtan Movement of the Tyennan Orogeny.

I would suggest one minor modification to this definition by Carey and Banks in the substitution of "Precambrian" for "Carbine Group" at the beginning of the paragraph above. At the present time the term Carbine Group as a division of the Precambrian has never been sufficiently well defined to allow its use beyond the type area at Dundas.

**Jukesian Unconformity.**—The Jukesian Unconformity has been defined as the angular discordance between the Dundas Group below and the Junee Group above, as revealed at the northern end of Mt. Jukes, south of Queenstown. Stratigraphically this unconformity may be considered as the erosional surface of the Dundas Group on which the Junee Group was deposited. From the tectonic viewpoint it may be considered as the expression of an orogenic movement of post-lower Upper Cambrian but pre-Lower Ordovician age. This movement is referred to as the Jukesian Movement of the Tyennan Orogeny. Hills (1914, pp. 45) was the first to give a detailed description of an unconformity between the Junee and Dundas Groups. In the Mt. Sorell and Mt. Jukes area he describes an angular and a metamorphic discordance between the two groups and the presence of a basal breccia dervide from the underlying Dundas Group. Unfortunately the section described by Hills at the north end of Mt. Jukes (p. 45) and taken by Carey and Banks as their type locality for the Jukesian Unconformity is not an unconformity but a metamorphic contact (Bradley, 1954, p. 206 and Solomon, 1957, p. 35). There is no doubt that a tectonic break exists at the top of the Dundas Group in this area and the author would suggest the South Darwin peak as the type locality for this unconformity. Here the regional trend in the Dundas Group is north-south with a steep dip of 80 degrees to the west; it contains the Darwin Granite and associated magnetite-hematite mineralisation. The overlying beds consist of a thickness of Jukes Breccia containing angular particles up to 12 inches in length of the underlying Dundas Group, granite and magnetite-hematite, as originaliy described by Hills (1914, p. 43). This Breccia grades upwards into a more normal siliceous chocolate coloured pebble Owen Conglomerate. This well bedded Conglomerate is folded into a shallow syncline which plunges to the south at approximately 20 degrees with dips of up to 25 degrees on the east and west limbs. Thus in this area there is a structural discordance between the Dundas Group and Owen Conglomerate, with an intervening period of granite emplacement, hematite-magnetite mineralisation and erosion to form the basal Jukes Breccia.

Throughout, I have found it difficult not to use the terms pre-Dundas Group and Precambrian synonymously although it is realised that the oldest fossils so far found in the Dundas Group have only been dated as upper Middle Cambrian (Opik, 1951*a*).

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## UNCONFORMITY BETWEEN JUNEE GROUP AND PRE-DUNDAS GROUP ROCKS

*a.* **Andrew River Area** (Mather, 1953, p. 15)

In this area the Dundas Group is absent and rocks correlated with the Owen Conglomerate, which is overlain by the Gordon Limestone, rest directly on the Precambrian (Fincham Group, see Table I). The actual contact between the Owen Conglomerate and the Fincham Group has only been observed in one stream section. In this section coarse grained Owen Conglomerate overlies a pinkish coloured quartz schist of the Fincham Group. The rocks on either side of the boundary have comparable attitudes. Along the regional strike to the north-west at about 1200 feet distant part of the base of the Owen Conglomerate is exposed. It consists of a coarse grained breccia conglomerate which contains angular and rounded fragments of quartz and white micaceous quartzite up to nine inches in size. The particles of micaceous quartzite are considered by Mather to have been derived from the underlying Fincham Group and to indicate erosional unconformity. Mather also considered the marked decrease in the stratigraphic thickness of the Fincham Group as it is traced along strike to the south-east to be due at least in part to erosion which took place between the late Precambrian and the deposition of the Owen Conglomerate (Lower Ordovician). The apparent conformity as expressed by the similar attitudes of the two is considered to be due to the shallow dip of the Precambrian in this area at the time of the deposition of the Owen Conglomerate. This would suggest broad folding of the Fincham Group prior to the deposition of the Owen Conglomerate; later folding has produced the present steep attitude of these sediments.

*b.* **Mt. Fincham Area** (McLeod, 1955, p. 13)

Similar conditions apply here as in the Andrew River area. The actual contact betwen the Owen Conglomerate and the Fincham Group was only seen in one place. Here breccias and conglomerates striking 100° and dipping 50° to the south occur within twelve inches of a purple quartzite of the Fincham Group whose strike varies from 090 to 120° with a dip of 70 to 80° to the south. At a number of other places rocks on either side of the contact were farther apart and the evidence for a structural unconformity between the Owen Conglomerate and Precambrian is less conclusive owing to the variable dips which occur in the latter.

A correlate of the Jukes Breccia was seen, occurring as half a dozen loose blocks which contained a predominance of rock particles up to three inchs in size but with some to six inches. The fragments include massive and schistose quartzites, micaceous schistose quartzites, and some reddish massive quartzite.

McLeod concludes that usually the strike of the Owen Conglomerate and older rocks is similar and that the unconformity is shown by a steeper dip of about 20 degrees in the latter rock. He suggests (p. 14) that part of the Owen Conglomerate was deposited around a hill or island of quartzites in the Lower Ordivician topography.

TABLE I.

*Lower Palaeozoic Stratigraphy*

| | |
|---|---|
| Gordon Limestone | |
| Florentine Valley Mudstone | |
| Caroline Creek Sandstone | JUNEE GROUP |
| Owen Conglomerate | |
| Jukes Breccia | |
| | DUNDAS GROUP |

*Precambrian Stratigraphy—Frenchman's Cap Area*

(after McLeod, 1955 and Spry, 1957)

| *Groups* | *Grade of Metamorphism* |
|---|---|
| Fincham Group | Chlorite zone |
| Franklin Group | Garnet zone |
| Mary Group | Chlorite zone |
| Joyce Group | Garnet zone |

*c.* **Elliott Range**

The Tyennan unconformity at the north end of Elliott Range was originally described by Carey and Banks (1954, p. 255). The unconformity is well exposed in a near vertical cliff section and consists of well bedded white quartzites and pebble conglomerates (Owen Conglomerate) which overlie Precambrian siliceous schists.

*d.* **Sprent River**

The exposures north and south of Sprent River indicate a broad anticlinal structure with a central portion of metaquartzites and siliceous schists and margins of quartz pebble conglomerate and sandstones which have been correlated with the Owen Conglomerate. The latter sediments form the prominent cuesta of Sprent Ridge which is immediately to the north of the Sprent River. On the western margin the strike of the Precambrian and Owen Conglomerate is comparable but with the suggestion of a steeper dip in the former sediments. On the eastern margin the Owen Conglomerate trends nearly north-south with the Precambrian horizons trending east-west. The overall structure can be best explained by an anticline in existence prior to the deposition of the Conglomerate with refolding after their deposition about an axis some one to two miles to the west of the previous one.

The above descriptions allow the establishment of an unconformity between the Junee Group and pre-Dundas Group rocks for a distance of 35 miles, from the north end of the Engineer Range (Mt. Madge) southwards to Mt. Lewis.

*e.* **Warnes Lookout** (Wells, 1955, p. 5)

The Owen Conglomerate has an irregular boundary with the underlying schists. The contact itself is not clearly visible and the possibility of a faulted

contact cannot be entirely discounted, especially on the western margin of this outlier of Conglomerate. However, on the eastern margin Wells states the existence of a breccia which contains angular fragments up to eight inches in length which he possibly correlates with the Jukes Breccia. Photogeological interpretation would place faults along the northern, western and southern margins of the outlier but the eastern contact with the underlying rocks is irregular in outline.

On this basis a Tyennan unconformity can be inferred at Warnes Lookout.

*f.* **Loddon River—Calder Pass**

Ward (1909, p. 50) described an unconformity in the Loddon River valley. The upper group of sediments, Ward's "pebbly conglomerate beds" and "tubicolar sandstone", are now known to be part of the Junee Group which rests directly upon the quartz mica schists of the area. Ward evidently noted this unconformity in more than one location for he writes:

> "The several members of this sedimentary series (Junee Group as above—author) rest directly upon the quartz-mica schists in every case which was observed, and there is a marked unconformity at the junction with the foliated rocks".

Later in this same report Ward (p. 34) describes the same unconformity further to the south, at Calder Pass. He writes:

> "The northern branch of the pass follows the line of junction between the tubicolar sandstone and the mica schists which constitute the eastern foothills of the Frenchman's Cap".

Finucane and Blake (1933) also recognised this unconformity from the South Loddon River where the basal members of their Silurian rocks could be seen resting unconformably on the Precambrian schists. At the base of these younger rocks they describe the presence of a coarse breccia-conglomerate which consists of "angular and rounded pebbles of quartz and quartzitic schist set in a highly siliceous ground mass; the schist pebbles are identical with the quartzitic schists of the Precambrian rocks and have doubtless been derived from them".

Wells (1955, p. 5) in discussing the geology of the Calder Pass describes "white silicified conglomerate containing pebbles of quartz of the order of one cm. diameter", which underlies the tubicolar sandstone. Although he did not examine the base of this Owen type conglomerate he considers it likely that an unconformity exists between these sediments (Junee Group) and the Precambrian rocks of the area.

A compilation of the work of Ward, Finucane and Blake, and Wells and using this as a basis of photogeological interpretation of the area has outlined a basin of 20 square miles of Palaeozoic rocks which rest directly on Precambrian, situated between the Loddon River and Calder Pass. Its north and south extremities appear to be primarily in faulted relationship with the Precambrian but the eastern and western edges of the basin would be the localities to seek the unconformity. It is the western edge which is described by Ward and Finucane and Blake.

*g.* **Bubbs Hills (16 miles east of Queenstown)**

Gould (1860, p. 12) was the first to be aware of the unconformity between the "Lower Palaeozoic rocks" and "metamorphic schists" in this general area.

Carey and Banks (1954, p. 255) infer an unconformable relationship between the Junee Group and pre-Dundas strata at Bubbs Hill. Recent mapping supports these previous observations (and those of Ward, 1908, p. 35 and map facing p. 44) of flat lying Gordon Limestone (capped by white Crotty Quartzite) which probably lies directly on contorted and steeply dipping Precambrian schists. Mapping approximately two miles to the north-east of Bubbs Hill established the presence of white fossiliferous quartzites (these were correlated with Crotty Quartzite on lithological grounds) which appear to directly overlie the Precambrian schists of the area. The Precambrian and Junee Group rocks both trend east-west but the former dip to the north at 60 to 80 degrees whilst the latter have a flatter dip, usually less than 45 degrees to the north. Thus although no actual erosion surface was exposed a Tyennan Unconformity can be said to exist, with some confidence.

*h.* **Mt. Arrowsmith** (Carey and Banks 1954, p. 257; Ward 1908, p. 37, and 1909, p. 32)

Two exposures of an unconformity between Owen type conglomerate and Precambrian siliceous schists were described by Ward (1908, 1909) on the summit of Mount Arrowsmith.

> "On the north-western portion of the summit of Mount Arrowsmith, and 1600 feet above the Franklin River Bridge, there is left an undenuded portion of a sedimentary basin, the full extent of which is not now clear. The strata consist of bedded shales, sandstones, and fine grained conglomerate which dip at an angle of five degrees to the west. The sandstone contains some imperfectly preserved impressions of brachiopods, which are probably of Silurian age. At this place the area covered by the sediments is very small, and fills a hollow in the hard quartzitic schist, to the endurance of which it owes its preservation. The rest of the summit of Mount Arrowsmith is wholly of the white foliated quartz schist".

Later on the same page Ward describes another unconformity on the east side of Mount Arrowsmith.

> "A low hill on the northern side of the Linda Track proved to be composed of medium-grained quartzite. In all respects this quartzite resembles very closely the reddish quartzite which is associated with the West Coast conglomerate. The dip is north-westerly, at an angle of 40 degrees. This formation rests upon a floor of quartzite schists . . .".

In the report for 1909 (p. 32) Ward describes this latter occurrence as resting unconformably upon the Precambrian schists.

*i.* **North End of Denison Range** (Carey and Banks, 1954, p. 257; Twelvetrees, 1908, p. 30)

Twelvetrees (1908) walked from the Rasselas Valley, with its occurrence of sediments of the Junee Group, westwards into the north end of the Denison Range, to Lake Curly, and beyond.

> "About a mile west of this the schist country is entered. The general strike of the strata now alters. Previously it was west of north (in the Rasselas Valley—author); now it is east of north, and this was a stable character as far west as we went. There is thus a strong unconformity between the Precambrian and the Cambrian strata".

Twelvetrees travelled as far west as the Prince of Wales Range. The Cambrian strata are now known to consist of the Owen type conglomerate, Gordon Limestone and the younger, Eldon Group, rocks of the Rasselas Valley and general Florentine River area.

> "At the junction of the systems . . . is a . . . breccia of large, angular stones of quartz and quartz schists, which is situated between the upper members of the schist and the basal sandstones of the conglomerate series".

This breccia corresponds to the Jukes Breccia. Approximately five miles to the north of Twelvetrees east-west traverse on the south side of the lower Gell River valley, a marked structural discordance is apparent between the Junee Group and underlying Precambrian schists. The structures are quite clear on the aerial photographs. The Owen type conglomerate (apparently now thinner than to the south) and overlying Gordon Limestone swing from a general strike of 345 degrees in the Rasselas Valley to 285 degrees in the Gell River Valley. The general dip to the north-east is maintained at both localities. The Gell River here marks the northern end of the Denison Range; at this northern termination the Precambrian schists of the Range maintain their regional strike of 020 to 030 degrees and plunge beneath the 285 degree trend of the overlying Junee Group.

*j.* **Tim Shea** (Carey and Banks, 1954, p. 252; Twelvetrees, 1908, p. 27 and 1909, p. 27)

Carey and Banks describe the unconformity which exists at Tim Shea between Owen type conglomerate and underlying Stephens Dolomite. The crest of Tim Shea is composed of Owen type conglomerate and quartzite which strike north-east and dip to the north-west at a shallow angle of about 15 degrees. The underlying Dolomite strikes north-west and dips at a steep angle to the north-east (70 to 80 degrees). Between the two a conglomerate exists which consists of particles of the underlying Dolomite.

This is the type locality for a Tyennan Unconformity.

The map on page 249 of Carey and Banks shows that the direction of folding in the Precambrian here is nearly N.N.W. whilst that in the overlying Junee Group is N.N.E. to north.

*k.* **Mt. Hopetoun** (Carey and Banks, 1954, p. 261; Stephenson, 1954, p. 151)

Mt. Hopetoun is six miles north-east of Federation Peak. The unconformity described by Stephenson at Mt. Hopetoun and correlated by Carey and Banks as possibly Tyennan is now most suspect. Recent photogeological work and regional considerations make it highly probable that the siliceous pebble conglomerate described by Stephenson is a Precambrian unit and not an Owen-type conglomerate of Ordovician age. This unconformity between conglomerate and underlying schist would then be placed within the Precambrian.

*l.* **Wedge River Valley** (Carey and Banks, 1954, p. 261 and Twelvetrees, 1909, p. 29)

On the basis of a regional compilation and photogeological interpretation of the general Adamsfield area the unconformity in the Wedge River Valley, provisionally correlated as Tyennan by Carey and Banks, is suspect. The determination of this point must await a more adequate definition of the age and structure of the sediments of the area between the Ragged and Junction Ranges (Denison Plain).

## UNCONFORMITY BETWEEN DUNDAS GROUP AND PRE-DUNDAS GROUP ROCKS

### *a.* Point Hibbs-Macquarie Harbour

The relationship in this area is complicated by the major faulting which is strongly suspected to be present along the contact of the two and by a belt of ultra-basic rocks which occurs along this eastern boundary from Point Hibbs to Macquarie Harbour. However, between Birch and Point Hibbs the direction of folding in the Dundas Group is N.W.-S.E. whilst immediately to the west of this in the Precambrian the regional strike and direction of folding is N.N.E. On this basis an unconformity between the two can be inferred.

### *b.* Adamsfield

At Adamsfield the occurrence of the serpentinite and overlying shales and conglomerate which consists entirely of particles derived from the serpentinite has been described by Carey and Banks (1954, p. 26). These sediments in turn are overlain by Owen type conglomerate. The age of these shales has recently been determined by Opik (pers. comm. M. R. Banks, 1959) who suggests that these rocks could be middle Uper Cambrian, thus placing the underlying unconformity as Stichtan. This exposure is approximately one mile east of the post office at Adamsfield, immediately north of the track. The base of the Palaeozoic/original top of the ultrabasic is also exceptionally well exposed at approximately one mile to the north of the former locality, on the south side of Hopper Creek.

The dating of these sediments has had the important corollary of placing the intrusion of the associated ultrabasic as being older than previously thought and as taking place prior to or during the deposition of the Dundas Group.

*c.* **Rocky Boat Harbour-Prion Bay** (Blake, 1938 and Banks, 1959)

Banks (1959) gave the first description of a probable Stichtan Unconformity in this area. The tough, grey dolomite with a trend of 010 degrees and an almost vertical dip is unconformably overlain by a sequence of polymictic conglomerates with minor siltstone and sandstone beds. Among other rock types the conglomerate contains particles of the underlying dolomite, and serpentinite. This sequence is in turn overlain by Owen type conglomerate. These rocks above the dolomite trend north-easterly and dip at angles of less than 45 degrees.

The dating of a similar unusual rock assemblage at the base or below the Junee Group at Adamsfield (page 106) as probably middle Upper Cambrian makes it probable that the assemblage here is also of a similar age. If this is correct the unconformity can be related to a Stichtan Unconformity.

## UNCONFORMITY BETWEEN JUNEE AND DUNDAS GROUPS

Usually in S.W. Tasmania the contact between the Owen Conglomerate and underlying Dundas Group has been complicated by major faults. Thus whilst structural discordances between the two may be apparent (e.g. at the D'Aguilar range) this could as well be due to faulting as to an unconformity, or a combination of the two.

*a.* **Mt. Jukes, Mt. Darwin, Mt. Sorell**

As already described on page 1, Hills (1914, p. 43) was the first to describe in detail a Jukesian Unconformity. His work has been largely confirmed by later workers as Bradley (1954, 1956) and Solomon (1957).

*b.* **Adam River**

Nye (1929, p. 10) inferred an unconformable relationship between the Owen type conglomerate of the Ragged Range and the underlying sediments exposed in the Adam River which were described by him as Cambrian in age. On lithological and structural grounds these latter sediments can be tentatively correlated with the Dundas Group. This correlation is supported by the recent dating of the sediments underlying the Owen type conglomerate at Sawback Range at Adamsfield as probably middle Upper Cambrian in age.

The conglomerate of the Ragged Range has a regional trend of 195 degrees and a dip of 45 to the east. The underlying sediments exposed in the Adam River below the falls are interbedded red and brown mudstone, light green and purple shales with red, cream and light-green coloured chert bands which trend 150 degrees and dip at 60 degrees to the east. On this basis an unconformity could be inferred between the two types of sediments but their actual contact at the Adam Falls is considered to be a faulted one.

*c.* **Prion Bay; Rocky Boat Harbour and Prettys Point**

Banks (1959) inferred an unconformity between the north-east trending Caroline Creek sandstone on the east side of Prettys Point and a south-east trending sequence of serpentinous conglomerates, sandstones and claystones further to the west. Elsewhere on the east side of Prion Bay these latter sediments underlie Owen type conglomerate. These serpentinous conglomerates, &c., resemble those at Adamsfield further to the north, as already described above. These former sediments at Adamsfield have been dated as probably middle Upper Cambrian thus making it possible that the same unusual rock assemblage at Rocky Boat Harbour is also Upper Cambrian.

Owing to the thickness of the bush in this area the critical area which is the coast line immediately to the west of Prettys Point could not be reached. A photogeological interpretation of this area indicates that the angular relationship described above is clear-cut and the possibility of it being due to a sharp swing in strike is considered to be remote.

## PALAEOGRAPHIC IMPLICATIONS

The implications of the three types of unconformity have already been outlined by Carey and Banks (1954, p. 265).

It is clear that the areas containing a Jukesian Unconformity received Dundas Group sedimentation, followed by Jukesian Movement, erosion and deposition of sediments of the Junee Group. The deposition of this Group began with the Jukes Breccia and coarse grained Owen conglomerate type of sedimentation as seen in the West Coast Range and the Sawback and Ragged Ranges at Adamsfield. It is most probable that progressively younger formations of the Owen type conglomerate overlapped the older which would be a corollary of a transgressive early Ordovician sea. It is to be noted that the transgressive sea would make the basal breccia-conglomerate of the Junee Group (Jukes Breccia-Conglomerate) transgressive in time, that is the correlate of the Jukes Breccia at Warnes Lookout and similar areas would probably be younger than the corresponding rock type at, say, Mt. Jukes or Mt. Darwin. As the sea transgressed, the land area between the two main basins of deposition at Adamsfield and on the West Coast would finally be completely reduced and either submerged or aproaching a peneplain. Sedimentation continued with deposition of the Caroline Creek Sandstone and the Gordon Limestone.

The structural discordances illustrated by the Stichtan Unconformity described above demonstrates that the pre-Dundas Group rocks were folded prior to the deposition of this Group. This direction of folding would appear to have been largely north-south although it is difficult to remove the effects of later orogenic movements from the pre-Dundas Group rocks in the absence of detailed structural studies. Later folding (post Lower Ordovician) was either approximately parallel to the existing axes (as at Sprent River) or discordant to it, as at the Tim Shea and Gell River localities.

A major problem is whether sediments of the Dundas Group were ever deposited on areas showing a Tyennan Unconformity. Sedimentation in the Dundas Group apears to thin rapidly towards these areas but two interpretations are possible. Either the Tyennan areas received a cover of Dundas sedimentation which was stripped off in the

ensuing Jukesian Movement to completely expose the underlying pre-Dundas rocks, or the Tyennan areas were emergent during this period. In my opinion a choice cannot yet be made between either alternative. A thin cover of Dundas sedimentation could have been deposited on the Tyennan areas—the thinning of these sediments towards the Tyennan areas could just as well be due to an erosional effect of the Jukesian Movement as a deposition thinning; there is no conclusive evidence yet available on this point.

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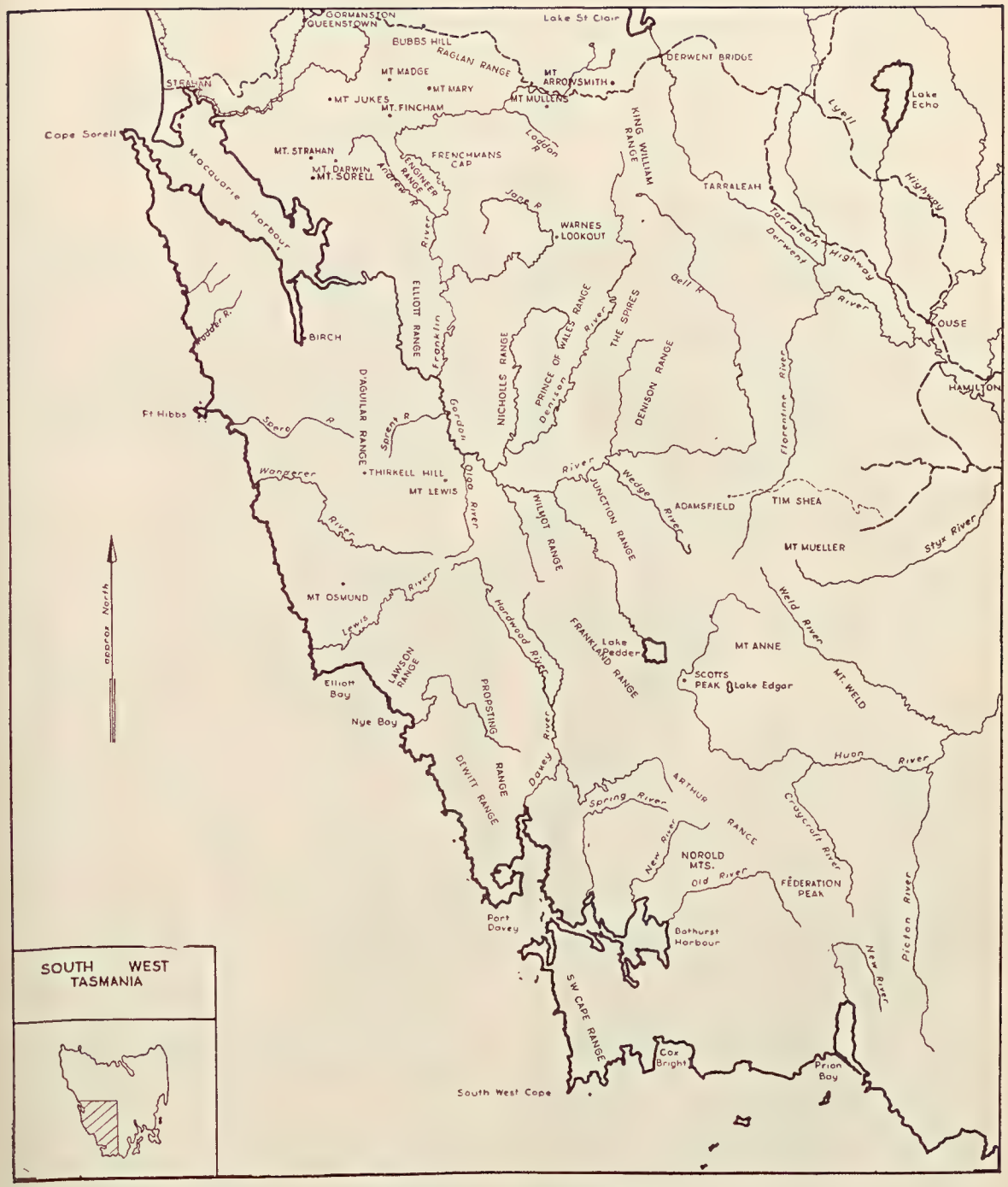
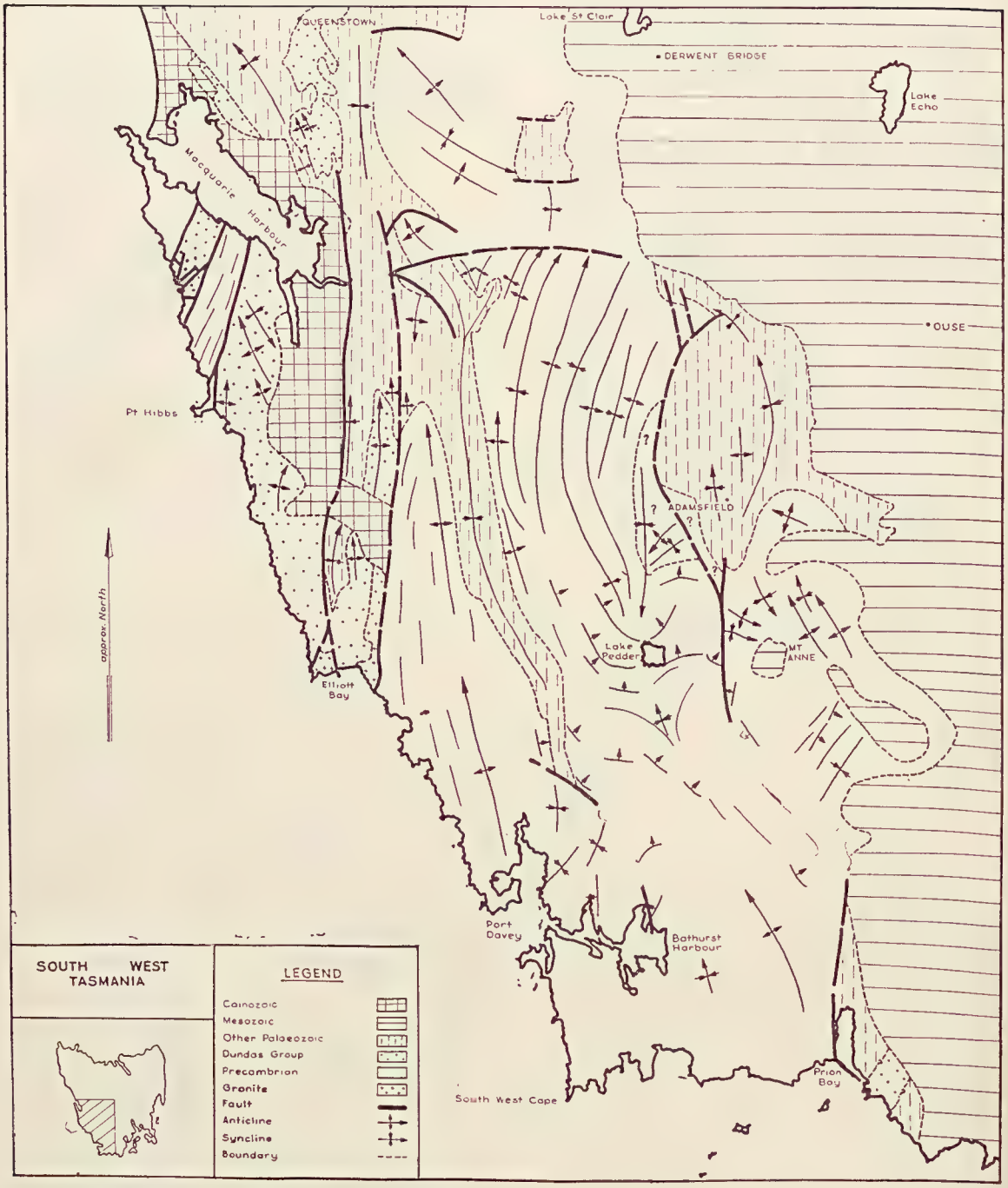



Scale: 16 miles to 1 inch.

FIGURE 1.—Location Plan of S.W. Tasmania.




Scale: 16 miles to 1 inch.

FIGURE 2.—General Geology of S. W. Tasmania.

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# OBSERVATIONS ON THE SKINK LIZARD
## *Egernia whitii* (*Lacépède*)

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(With 3 figures in the Text and 1 Plate).

### ABSTRACT

Observations on the habitat, activity, food, reproduction, growth, moulting, longevity and abnormalities of the lizard *Egernia whitii* (*Lacépède*) are recorded. Information on the keeping of the lizard in captivity is given. *E. whitii* is most active at temperatures between 24°C. and 29°C. becoming dormant below 13°C. It feeds largely on ants, beetles, bugs and spiders. In the vicinity of Hobart mating of the lizard takes place in October. Pregnant females carry from one to five embryos and most births occur in February. *E. whitii* takes at least four years to attain a snout-vent length of 80 mm. and moults from three to five times a year. Its life span is estimated to be more than eight and a half years.

### INTRODUCTION

In the course of studying the life-history of the cestode *Oochoristica vacuolata* Hickman, which occurs as a parasite in the lizard *Egernia whitii*, the opportunity was taken to record some observations on the biology of the lizard itself. These observations are set out in the present paper.

Although the lizard is common and widely distributed in Australia, the only information concerning its habits are the brief comments of McCoy (1890), Lucas and Frost (1894), Waite (1929) and Hewer (1948). Up till now there has been no record of the lizard climbing trees. In fact McCoy (1890) and Waite (1929) claim that *E. whitii* does not climb trees.

Lucas and Frost (1894) mention that its food consists chiefly of insects and that in captivity it will feed on smaller lizards. They also record an instance of the lizard swallowing its own detached tail. Hewer (1948) refers to its eating "small fruits such as strawberries, &c". These brief observations appear to be all that have been recorded concerning the food of the lizard.

The only reference to the longevity of *E. whitii* is that of Flower (1925), who records the lizard as living in the Zoological Garden, London, for three years, two months and sixteen days. Flower also makes reference to a record of a related species, *E. cunninghami*, as living in the Jardin des Plantes, Paris, for nineteen years, eleven months and four days.

Lord and Scott (1924) claim the lizard to be "a common species in many localities" in Tasmania and Hewer (1948) refers to its occurring "all over Tasmania from sea-level to mountain top". Apart from these general remarks on the distribution of the lizard in Tasmania, the only references to its occurring at specific localities in the State or on adjacent islands are those of Lucas and Frost (1894), who record it from King Island and the Kent Group, and Hewer (1951), who mentions that it occurs on Betsy Island.

The length of the lizard seems to vary considerably. In South Australia, according to Waite (1929), it reaches a total length of 355 mm., but is better known as a somewhat smaller lizard. Lucas and Frost (1894) give the total length as 295 mm. and the tail length as 185 mm. They state, however, that in Victoria it rarely exceeds a total length of 250 mm. Lord and Scott (1924) record the average total length as 300 mm. and the tail length as 187 mm. More recently Hewer (1948) states that "mature specimens usually about 10 inches, although larger specimens are sometimes found".

In the present study it will be shown that of 350 specimens measured, none attained such lengths. It is possible that the higher average day temperatures in South Australia and Victoria may account for the lizard growing to a larger size in those States.

### KEEPING *EGERNIA WHITII* IN CAPTIVITY

It is possible to obtain new-born lizards by collecting from the field females in advanced stages of pregnancy and keeping them in a suitable vivarium until the young are born. The vivarium used in the present investigation consisted of a wooden enclosure about 274 cm. long, 91 cm. wide and 20 cm. deep, partly lined with galvanised iron, which was sunken into the ground to a depth of about 20 cm. in order to prevent the lizards from burrowing out. The enclosure was provided with a movable wire-mesh cover and a small door for the admission of insects serving as food. The whole structure was located out-of-doors in a garden. Some eight or more large flat stones and several grass tussocks were placed in the vivarium to provide adequate cover for the lizards.

About eight pregnant females were kept in the enclosure, which was inspected regularly. As the young lizards were found, which was usually soon after birth, they were immediately removed. Each specimen was placed in a small wooden box (about 18 cm. long, 10 cm. wide and 10 cm. deep) fitted with a glass front and a wire-mesh top. The box was filled to a depth of about half an inch with earth. A small flat stone under which the lizard might hide was placed in the box. The

boxes were kept in a sun-room which received direct sunlight for most of the morning. The young lizards were offered termites, small ants and spiders as food. These they would readily take after the first day. Water for them to drink was periodically sprayed into the box. On hot days, after a period of exposure to the sunlight, the boxes were shaded to avoid overheating the lizards. Fifteen young lizards born in captivity were raised in this way.

By daily visits to the field during the months in which the females give birth to their young another thirty-four newly born lizards were obtained. These were kept in a manner similar to that employed in the case of those born in captivity.

Single adult specimens lived satisfactorily in separate wooden boxes, 52 cm. long, 22 cm. wide and 18 cm. deep. The top of each box was fitted with a movable glass lid leaving a gap of about 10 cm. by 22 cm. at one end. This gap was closed with a wire-mesh door for ventilation. The box was filled with earth to a depth of five to eight centimetres. A small jar, sunk in the soil at one end of the box was kept filled with water. A 25-watt globe placed at the end of the box opposite to the wire door provided artificial heating when required. A flat stone, about 15 cm. long, 18 cm. wide and 5 cm. deep, placed in the box near the door, served for the lizard to hide under and also for it to rub against when moulting. Ants (adults, larvae and pupae), termites, spiders, beetles and flies provided a varied diet on which the lizards thrived.

## DISTRIBUTION AND HABITAT

*Egernia whitii* occurs not only in Tasmania, but also in Victoria, New South Wales, Queensland, South Australia, Western Australia and Central Australia. Its distribution within Tasmania has not been studied systematically, but I have collected it at the following places:—Table Cape, Burnie, Trevallyn, Mt. Rumney, Lindisfarne, Risdon, Ridgeway, Mt. Nelson and the Queen's Domain, and received specimens from Orford and Sandfly.

In the vicinity of Hobart the lizard occurs from sea level on the Queen's Domain to an altitude of approximately 1,200 feet at Ridgeway. It favours the more exposed areas on rock-strewn slopes, which face east, north or north-west and which have a friable top soil. In such localities *E. whitii* may often be seen sunning itself on top of a rock, on grass tussocks or on bare areas of soil between the tussocks. It frequently hides in burrows made in cracks in the soil, at the sides of roots of trees, or under stones. Such retreats usually have at least two openings, possibly serving for ventilation or for easy escape if necessary.

## ACTIVITY

To investigate the feeding activity of the lizard, specimens collected on the Queen's Domain during each month of the three year period, 16th September, 1954, to 15th September, 1957, were chloroformed, dissected and the gut contents examined. The presence or absence of food in each of the three regions of the alimentary canal—stomach, small intestine, and large intestine—was noted. A lizard which had food in any two of these regions was considered to have been feeding more actively than one which had food in only one region or one which had no food present in any region of the gut. The feeding activity of 150 specimens of the lizard was examined on this basis. The results analysed for the three year period are shown in Table 1. Feeding is seen to be at a maximum from November to March. During June, July and August when the average maximum temperature is below 13°C., the lizards exhibit a minimum of activity and the majority of them hibernate in holes in the ground or under stones.

Table 1. Anaysis of the feeding activity of *Egernia whitii* for the period 16th September, 1954, to 15th September, 1957.

| Month | Number of specimens of *E. whitii* examined | with no food in gut | with food in 1 region of gut | with food in 2 regions of gut | with food in 3 regions of gut | Daily average sunshine (in hrs.) | Mean max. temp. in degrees Cent. |
|---|---|---|---|---|---|---|---|
| Jan. .. | 8 | 0 | 0 | 1 | 7 | 8.1 | 21.3 |
| Feb. .. | 9 | 0 | 0 | 1 | 8 | 6.5 | 21.5 |
| Mar. .. | 33 | 0 | 1 | 1 | 31 | 6.1 | 20.1 |
| April .. | 15 | 0 | 1 | 3 | 11 | 4.8 | 17.4 |
| May .. | 11 | 0 | 1 | 2 | 8 | 4.1 | 13.7 |
| June .. | 6 | 2 | 3 | 1 | 0 | 3.6 | 12.1 |
| July .. | 6 | 2 | 3 | 0 | 1 | 4.8 | 11.3 |
| Aug. .. | 6 | 2 | 4 | 0 | 0 | 4.5 | 12.9 |
| Sept. .. | 11 | 0 | 4 | 3 | 4 | 5.8 | 14.8 |
| Oct. .. | 25 | 0 | 5 | 6 | 14 | 6.2 | 16.2 |
| Nov. .. | 13 | 0 | 0 | 2 | 11 | 6.6 | 17.3 |
| Dec. .. | 7 | 0 | 0 | 1 | 6 | 7.2 | 20.3 |

An analysis of the feeding activity in relation to the size of lizards collected during the months May to August inclusive is given in Table 2. The analysis indicates that during these months, when activity falls to a minimum, it is the young or small lizards that show the greater activity. Moreover, in the early morning of a day in December young lizards were observed to come out of their

Table 2. Analysis of feeding activity of *E. whitii* in relation to size of specimen collected in the months May-August (inclusive) during the period 16th September, 1954, to 15th September, 1957.

| Lizard with Snout-Vent length | Number of specimens of *E. whitii* examined | with no food in gut | with food in 1 region | with food in 2 regions | with food in 3 regions |
|---|---|---|---|---|---|
| Less than 60 mm. | 13 | 1 | 3 | 2 | 7 |
| More than 60 mm. | 16 | 5 | 8 | 1 | 2 |

burrows to sun themselves at least half an hour before the older lizards in the same area appeared. It would therefore seem that small lizards become active earlier and remain active longer than do large lizards.

From observations of the habits of lizards kept in captivity, activity and feeding are at a maximum at temperatures between 24°C. and 29°C. Above these temperatures the lizards seek shade under cover of stones or grass. On very hot days in summer, they sun themselves and feed in the mornings and afternoons, but retreat into their burrows or under stones in the heat of mid-day. When sunning themselves they part their hind legs and flatten the body, so as to bring the ventral surface to the trunk against the ground or stone on which they are resting.

In loose soil *E. whitii* is capable of digging actively. It quickly excavates a burrow under a stone, using its right or left manus to scratch out the soil. Freshly excavated earth at the side of a stone is often an indication of the presence of the lizard in its burrow.

In warm weather the lizard is able to run with considerable speed, the head being lifted up slightly above the ground, while the tail is dragged over the surface. Jumping is rarely exhibited by *E. whitii*. However, it will sometimes spring off the ground in order to snap at a fly which is hovering near by. Occasionally the lizard will climb a tree as was observed late one afternoon, when a specimen was noticed basking in the last rays of the sun, about sixty centimetres up the trunk of a Prickly Box (*Bursaria spinosa*).

In capturing an insect or other prey the lizard usually moves into a position, where it is able to snap at the head of its victim. It then straightens its fore-limbs, raises its head, arches its neck and strikes suddenly at its prey in an endeavour to swallow it head first. If the prey is large or too hard, the lizard will often attempt to crush it by seizing it with its jaws and rubbing it on the soil or against a stone. In the act of swallowing large insects the lizard sometimes stretches its neck by moving its head forwards and upwards and then from side to side.

Water is obtained by using the tongue to lick dew and rain off the surface of stones and grass. In captivity water is readily taken from the end of a glass pipette. After drinking the lizard sometimes makes a peculiar clicking noise with its jaws.

Depending on food-intake and temperature conditions, defecation occurs once or twice a day. On warm days faeces may be passed once in the morning and again in the afternoon. It usually takes three days for food to pass through the alimentary canal. The lizard often goes to a definite site to defecate, generally near the place where it suns itself. Here faecal pellets collect, unless carried away by coprophagous insects.

When irritated *E. whitii* will sometimes raise the head and front of the body, open the mouth and attempt to bite.

## FOOD

Lizards kept in captivity appeared to tire of the one kind of food. They would frequently refuse to eat until an alternative food was provided. That *E. whitii* likes a change in its diet is further indicated by the great variety of food found in the stomachs of lizards collected in the field. A summary of the food present in the alimentary canal of 197 lizards from the Queen's Domain is given in Table 3. The food, in order of frequency of occurrence, consists of Insecta, Arachnida, Crustacea, Myriapoda, Gastropoda and Oligochaeta.

*Insecta.*—Hymenoptera occurred in the food of 99.4% of the lizards examined. The most frequent Hymenoptera, the Formicidae, were represented by several unidentified Dolichoderinae and species of the genera *Pheidole, Polyrachis, Promyrmecia, Orectognathus* and *Camponotus*. Ants formed part of the food in every month of the year and were particularly numerous in the food consumed during the summer. The stomachs of several young lizards (about one month old) contained 30-40 small ants belonging to the Dolichoderinae and Myrmicinae. The Ponerinae and Camponotinae appeared more frequently and in greater numbers in the food of the older lizards, the common Sugar Ant (*Camponotus consobrinus*) being especially evident.

Coleoptera occurred in 44.7% of the lizards. Rarely more than six beetles were found in any one specimen. As might be expected the large family Curculionidae predominated.

Hemiptera, the only other insect group forming a major part of the skink's diet, were present in 32.5% of the lizards and were represented mainly by Heteroptera.

Lepidoptera, Diptera and less frequently Orthoptera, Thysanoptera and Odonata also occurred in the food.

*Arachnida.*—The gut of 39.5% of the lizards contained Arachnida, mainly spiders. The latter formed part of the food every month of the year.

*Crustacea.*—Terrestrial Isopoda occurred in 14.2% of the lizards and were represented by *Porcellio scaber, Armadillidium vulgare* and *Eluma caelatum*.

*Myriapoda* (mainly Chilopoda), *Gastropoda* and *Oligochaeta* were occasionally present but formed only an insignificant part of the food.

Flowers and seeds, possibly swallowed by the lizard when capturing insects, were the only plant material found in the gut of the lizards.

## REPRODUCTION

In the vicinity of Hobart mating of *E. whitii* occurs in October. On one occasion a male was observed to chase after a female and, using his jaws, to seize her at the sides of the thorax immediately behind the left forelimb. He then attempted to bring his body close to hers and to insert into her cloaca a hemipenis, which was protruding from his own cloaca. The female, however, freed herself and escaped.

TABLE 3

Summary of food of *Egernia whitii*

| Months | Number of Lizards Containing | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Lizards Examined | Hymenoptera | Formicidae | Ichneumonidae | Braconidae | Chalcididae | Unidentified | Coleoptera | Curculionidae | Carabidae | Scarabaeidae | Chrysomelidae | Elateridae | Tenebrionidae | Dermestidae | Staphylinidae | Pselaphidae | Byrrhidae | Larvae | Unidentified | Hemiptera | Heteroptera | Homoptera | Lepidoptera | Adult | Larvae | Diptera | Orthoptera | Thysanoptera | Odonata | Arachnida | Araneida | Acarina | Opiliones | Myriapoda | Chilopoda | Diplopoda | Crustacea (Isopoda) | Porcellionidae | Armadillidiidae | Gastropoda | Oligochaeta |
| January .. .. | 8 | 8 | 8 | ... | ... | ... | ... | 6 | 3 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 4 | 4 | ... | ... | ... | ... | ... | 5 | 8 | 1 | 1 | 1 | 8 | ... | 1 | 8 | 1 | 2 | 1 | 1 | ... | ... |
| February .. | 43 | 42 | 42 | ... | ... | ... | 6 | 23 | 10 | 4 | 2 | 2 | 2 | 3 | 3 | ... | ... | ... | 3 | 7 | 7 | 7 | ... | 1 | 1 | ... | 6 | 4 | 1 | ... | 13 | 13 | ... | ... | 1 | 1 | ... | 3 | 2 | ... | ... | ... |
| March .. .. | 41 | 39 | 39 | ... | 1 | ... | 3 | 13 | 5 | 2 | ... | 3 | 2 | ... | ... | ... | 1 | 1 | ... | 6 | 15 | 12 | 3 | 7 | 6 | 1 | 6 | 7 | .. | ... | 18 | 17 | 2 | 1 | 1 | 1 | ... | 5 | ... | 2 | ... | ... |
| April .. .. | 15 | 15 | 15 | ... | ... | 1 | 5 | 7 | 5 | ... | ... | 1 | ... | ... | ... | ... | ... | ... | 1 | 3 | 7 | 7 | ... | 2 | 2 | ... | 2 | ... | .. | ... | 7 | 7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| May .. .. | 11 | 11 | 11 | ... | ... | ... | 4 | 4 | 2 | ... | ... | ... | ... | ... | ... | 1 | ... | ... | ... | 2 | ... | ... | ... | 3 | 3 | ... | ... | 1 | 1 | ... | 3 | 3 | ... | ... | 2 | 2 | ... | 1 | ... | 1 | 1 | ... |
| June .. .. | 6 | 4 | 4 | ... | ... | ... | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 | ... | .. | 1 | ... | ... | 1 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| July .. .. | 6 | 3 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | .. | .. | .. | ... | 2 | 2 | ... | ... | ... | ... | ... | 1 | ... | 1 | ... | ... |
| August .. .. | 6 | 4 | 4 | ... | ... | ... | ... | 1 | 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | ... | 1 | .. | . | ... | ... | 1 | 1 | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| September .. | 11 | 11 | 11 | ... | ... | ... | 2 | 5 | ... | ... | 2 | ... | 1 | 1 | 1 | ... | ... | ... | ... | 5 | 2 | 2 | ... | 1 | ... | 1 | 1 | ... | ... | ... | 6 | 5 | 1 | ... | 1 | 1 | ... | 3 | 2 | 1 | 1 | ... |
| October .. .. | 30 | 29 | 29 | ... | ... | ... | 3 | 20 | 7 | 1 | 6 | 2 | 4 | ... | ... | ... | ... | ... | ... | 5 | 15 | 15 | ... | 8 | 3 | 6 | 7 | ... | ... | ... | 14 | 13 | 2 | ... | ... | ... | .. | 9 | 1 | 8 | 3 | ... |
| November .. | 13 | 13 | 13 | 1 | ... | ... | 4 | 12 | 8 | 1 | 2 | 1 | ... | 1 | ... | 1 | ... | ... | ... | 2 | 10 | 10 | ... | 4 | ... | 4 | 3 | ... | ... | ... | 4 | 4 | ... | ... | 1 | 1 | ... | 4 | 2 | 2 | ... | 1 |
| December .. | 7 | 7 | 7 | 1 | ... | ... | ... | 7 | 4 | 5 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 4 | 4 | ... | 2 | 1 | 1 | 2 | ... | ... | ... | 7 | 7 | ... | ... | ... | ... | ... | ... | ... | ... | 1 | 1 |

The lizard is viviparous. In a female carrying three embryos, two were in the right and one in the left uterus. The maximum number of embryos found in any one female was five. Though most births are in February, some take place in the last week of January and others do not occur until March or April. The mother bears her young in cavities under stones or in holes in the ground. The newly-born lizard is quite active and after moulting is ready to feed. The umbilical scar on the ventral surface of the body remains for some time and was still evident on a lizard having a length of 61 mm. from snout to vent.

The fact that occasionally a one year old lizard may be found together with a fully grown adult under the same stone, suggests that the young may remain with the parent for at least a year.

The size and age at which sexual maturity is reached was not definitely discovered. The smallest pregnant female measured 182 mm. in total length and 78 mm. from snout to vent. However, from the well developed condition of the ovary in lizards measuring 140 mm. in total length and 58 mm. from snout to vent, sexual maturity of the female might be attained in specimens measuring less than 78 mm. from snout to vent.

## GROWTH, MOULTING AND LONGEVITY

At birth the young lizards have the following measurements in millimetres:—Total length 70-92, tail length 35-53 and snout-vent length 35-39. Three hundred and fifty specimens including young and adult were measured and although the majority of the larger lizards measured 182-207 mm. in total length, 102-122 mm. in tail length and 80-85 mm. in snout-vent length, the largest had a total length of 219 mm., a tail length of 129 mm. and a snout-vent length of 90 mm.

The growth in tail length relative to that in snout-vent length is shown in Fig. 1. Because of the occurrence of broken and regenerated tails and the possibility that some such tails may not have been detected, only the maximum tail length for each snout-vent length is plotted.

From the frequency histograms (Figs. 2 and 3) of the snout-vent length of specimens collected during the periods January to March and Sep-

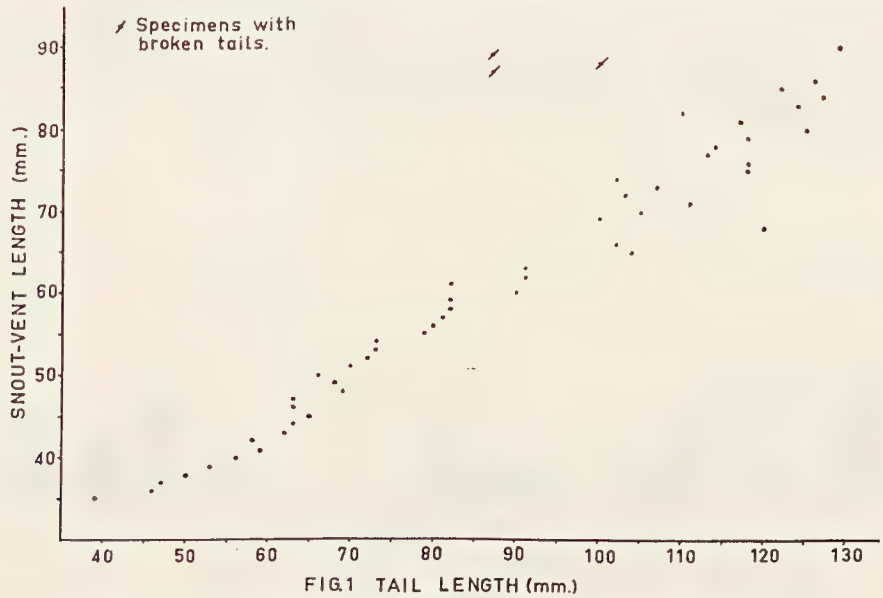


FIG. 1.—*Egernia whitii*. Snout-vent lengths relative to tail lengths in fifty-five specimens.

tember to November, it may be seen that in the first year the lizard grows to a snout-vent length of 51-60 mm. Compared with the corresponding measurement at birth, this is an increase in snout-vent length of 12-25 (mean 19) mm. A lizard raised in captivity showed a similar increase in the first year. Its snout-vent length grew by 18 mm. in the first year, by 9 mm. in the second year and by 8 mm. in the third year. After 42 months its snout-vent length measured 75 mm. At such a rate of growth *E. whitii* would require at least four years to attain a snout-vent length of more than 80 mm. However, growth may be extremely slow as is evidenced by the fact that a lizard raised in captivity measured only 50 mm. in snout-vent length after 34 months.

Scales found in the gut of one-day-old lizards and in the faces of four-day-old lizards raised in captivity indicate that *E. whitii* moults at birth. The discovery of scales in the gut of lizards collected in the field during January, February, March, May, October, November and December, together with observations on the moulting of specimens in captivity, indicates that moulting may occur in any month with the exception of June,

July and August. The record of moulting of two full grown lizards collected in the field and of four young specimens born in captivity is shown in Table 4. It is seen that *E. whitii* undergoes three to five moults a year, the average number being four.

Temperature has a marked influence on moulting.. This is clearly shown by the fact that lizards in vivaria at 26°C. ± 3° doubled their moulting rate. Moreover, if a specimen, which from the dark appearance of its skin is seen to be about to moult, be kept at a temperature below 15.5C., it will fail to mould and consequently die.

The scales on the head and dorsal surface of the trunk are the first to come off and are removed by the lizard rubbing against grass, stones and other objects. Frequently the skin covering the tail comes away in one piece. On several occasions *E. whitii* was observed pulling the skin off its limbs with its teeth, a habit which may well account for the presence of scales in the gut. In some specimens the almost complete glove-like integument of the manus was found in the alimentary canal.

One lizard, which from its size was at least four years old when collected, lived in captivity from 1st December, 1954, to 26th May, 1959, a period of four years five months and 25 days. It is therefore probable that *E. whitii* has a life span of at least eight and a half years.

## ABNORMALITIES

Among the three hundred and fifty lizards examined was a specimen having a forked tail. The lizard was 167 mm. in total length. The tail measured 87 mm. and the bifurcation occurred 65 mm. from the vent. Another specimen appeared club-footed. The third and fourth digits of the right forelimb and the second third and fourth digits of the right hind limb were missing. All the remaining digits on the limbs of both sides were represented merely by their bases, only three dorsal scales in each case being present. The club-footed appearance was obviously the result of mutilation, perhaps due to the lizard endeavouring to remove the integument of the digits with its jaws when moulting.

The possibility of self mutilation occurring in lizards renders the clipping of digits as a means of identification not dependable.

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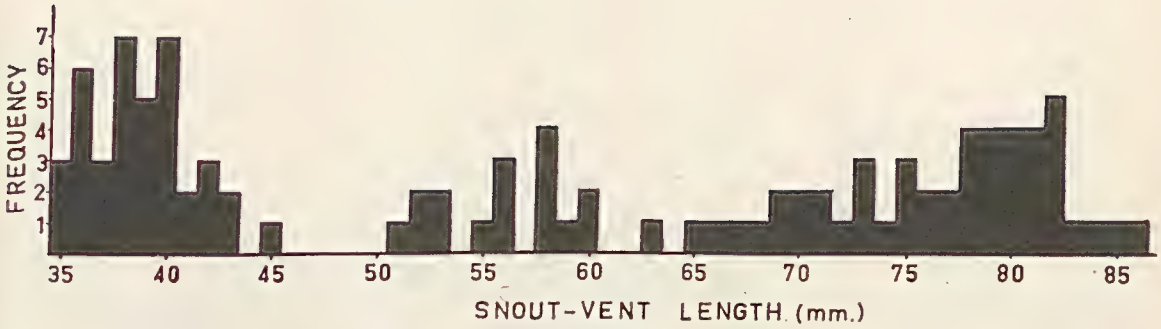



FIG. 2

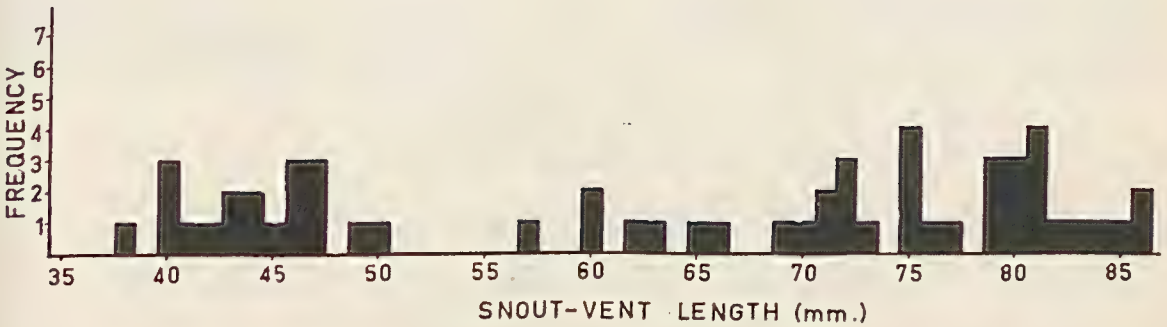



FIG. 3

FIG. 2.—*Egernia whitii*. Frequency histogram of snout-ve nt lengths of lizards collected in the months of January to March inclusive during the period 16th September, 1954, to 15th September, 1957.

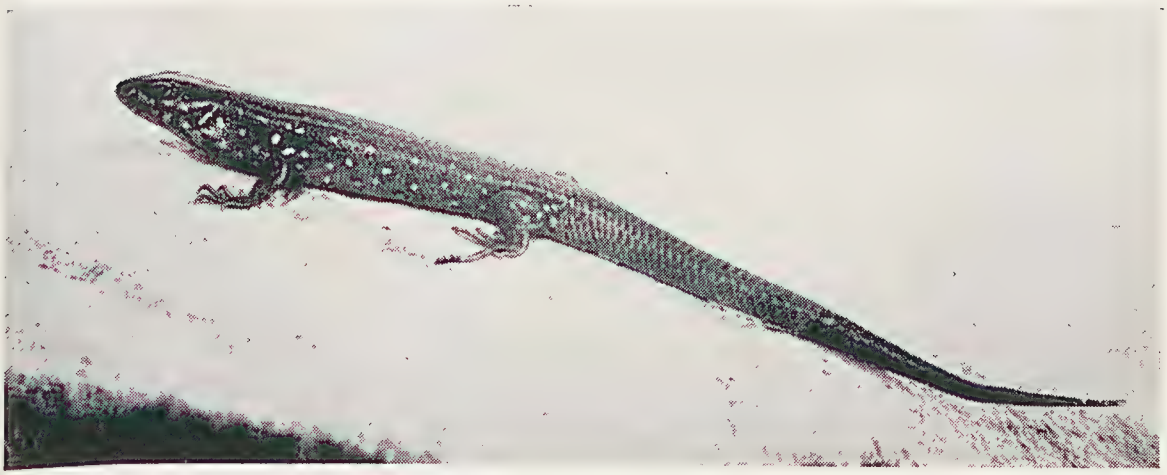
FIG. 3.—*Egernia whitii*. Frequency histogram of snout-vent lengths of lizards collected in the months of September to November inclusive during the period 16th September, 1954, to 15th September, 1957.

TABLE 4

Moulting of *Egernia whitii* in captivity

| Specimen No.* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| Date of moult | Period between moults | Date of moult | Period between moults | Date of moult | Period between moults | Date of moult | Period between moults | Date of moult | Period between moults | Date of moult | Period between moults |
| 22.2.56 | | 23.2.56 | | 24.2.56 | | 26.2.56 | | 9.2.56 | | 28.1.56 | |
| 14.11.56 | 266 | 29.9.56 | 219 | 11.11.56 | 261 | 5.10.56 | 222 | 13.10.56 | 247 | 5.5.56 | 98 |
| 22.12.56 | 38 | 26.11.56 | 58 | 17.12.56 | 36 | 7.12.56 | 63 | 14.12.56 | 63 | 19.9.56 | 137 |
| 22.2.56 | 62 | 4.1.57 | 39 | 30.3.57 | 103 | 14.1.57 | 38 | 18.1.57 | 35 | 5.12.56 | 77 |
| 2.11.57 | 253 | 4.2.57 | 31 | 14.11.57 | 229 | 23.2.57 | 40 | 11.3.57 | 52 | 30.1.57 | 56 |
| 11.12.57 | 39 | 20.3.57 | 44 | 30.12.57 | 46 | 19.10.57 | 238 | 19.10.57 | 222 | 30.3.57 | 59 |
| 15.2.58 | 66 | 4.11.57 | 239 | 25.2.58 | 57 | 18.11.57 | 30 | 11.12.57 | 53 | 28.9.57 | 182 |
| | | 28.12.57 | 44 | | | 16.12.57 | 28 | 23.1.58 | 43 | 16.12.57 | 79 |
| | | 10.3.58 | 72 | | | 2.2.58 | 48 | 24.3.58 | 60 | 12.2.58 | 58 |
| Average number of moults/year .. 3 | | 4 | | 3 | | 4 | | 4 | | 4 | |

* Specimens 1–4; raised in captivity.
5 and 6; collected from the field.



EXPLANATION OF PLATE

*Egernia whitii*. Specimen born and raised in captivity. Three years and eight months old. Total length 168 mm.

# PAPERS AND PROCEEDINGS

OF

# The Royal Society of Tasmania

## Volume 95

Edited by William Bryden

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PUBLISHED BY THE SOCIETY

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1961.

# The Royal Society of Tasmania

Volume 95

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# Royal Society of Tasmania

## Papers and Proceedings Volume 95

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# Royal Society of Tasmania

*Annual Report for the Year ended 31st December, 1960.*

The membership total of the Society reached 589, of whom 222 were listed on the Northern Branch centred in Launceston.

During the year the following lectures were given:—

March (Annual Meeting): "Western Tasmania" by Mr. Lloyd Jones.

April: "Experiment in Leadership Development" by His Excellency the Right Honourable the Lord Rowallan, K.T., K.B.E., M.C., President of the Society.

May: "Early Settlement at Oatlands and Jericho" by Mr. K. R. von Stieglitz, O.B.E.

June: "Hobart: Then and Now" by Mr. E. R. Pretyman.

July: "Phosphates in Relation to Australian Soils and Agriculture" by Dr. C. S. Piper.

August: Clive Lord Memorial Lecture.

September: "The Early Days of the Legal Profession in Launceston" by the Honourable Mr. Justice Crawford.

October: "Control and Conservation of Animals" by Mr. M. G. Ridpath.

November: "Kuru—A Problem in Human Genetics" by Professor A. M. Clark.

### Clive Lord Memorial Medal and Lecture.

The Council invited Emeritus-Professor V. V. Hickman to accept the Clive Lord Memorial Medal and to deliver the Lecture. Professor Hickman has a long and distinguished record as a zoologist and University teacher and on numerous occasions he held office in this Society.

The medal was presented to Professor Hickman by the President, His Excellency the Lord Rowallan.

The title of Professor Hickman's illustrated address was "Some little known Tasmanian Animals of particular Interest."

### Annual Meeting.

The Annual Meeting was held on Tuesday, 1st March.

The Society was honoured when His Excellency, the Lord Rowallan, accepted office as President of the Society. The Senior Vice-President, Mr. L. W. Miller, referred to the association of Governors of Tasmania with the Royal Society since its inception and then asked Lord Rowallan to take the Chair.

The following Office-bearers were elected:—

*Vice-President*: Under the Society's Rules, Mr. L. W. Miller retired from the office of Vice-President and Mr. R. M. H. Garvie was elected to fill the vacancy.

*Honorary Secretary and Librarian*: Dr. W. Bryden.

*Honorary Treasurer*: Mr. G. E. A. Hale.

*Honorary Auditor*: Mr. A. M. Hewer.

*Members of Council*: Under Rule 21, Mr. Justice Crisp and Mr. R. M. H. Garvie retired from the Council. Mr. D. H. Borchardt and Mr. L. W. Miller were elected for a period of three years.

### Committees, &c.

The following appointments for the year were made by the Council:—

*Standing Committee*: Dr. D. Martin, Mr. R. M. H. Garvie, Mr. W. F. Ellis, Dr. W. Bryden (Honorary Secretary).

*Representatives on the Board of Trustees of the Tasmanian Museum and Art Gallery*: Mr. G. F. Davies and Dr. D. Martin.

*Representative on the Board of Trustees of the Botanical Gardens*: Mr. R. S. McIntyre.

*Representative on the Nomenclature Board*: Mr. E. R. Pretyman.

*Representative on the Mount Field National Park Board*: Dr. D. Martin until November, 1960. Dr. J. M. Gilbert from November, 1960.

*Representative on the Library Association of Australian (Tasmanian Branch)*: Dr. W. Bryden.

### Library.

Four hundred and ninety-one volumes, made up of books and journals, were added to the Library during the year. There are now 32,685 volumes in the Library. The number of Institutions on the exchange list is 318.

### Papers and Proceedings.

Volume 94 of the *Papers and Proceedings of the Royal Society of Tasmania* was published during the year under review.

### Thanks.

The thanks of the Society are extended to the Government of Tasmania, to the University of Tasmania, to the Press and the Australian Broadcasting Commission, to the donors of books, prints, documents, &c., and to all who have assisted the Society during the year.

President.

# Northern Branch

*Annual Report*, 1960.

During 1960, the Council of the Northern Branch of the Royal Society of Tasmania was composed as follows:—

Chairman: Dr. C. Craig.

Vice-Chairman: Mr. John Lord.

Past Chairman: Mr. G. H. Stancombe.

Honorary Secretary and Treasurer: Mr. W. F. Ellis.

Members of Council: Mrs. I. J. Mead, Mr. T. E. Burns, Rev. C. O. Leigh-Cook, Mr. T. W. W. Sharpe, Mr. K. R. von Stieglitz.

Dr. Craig and Mr. Ellis acted as representatives of the Northern Branch on the General Council of the Society and Mr. Ellis served as a member of the Standing Committee. Mr. Justice G. H. Crawford continued as the Northern Branch nominee on the Cradle Mountain-Lake St. Clair National Park Board.

## Membership.

Twenty-two members were elected to the Branch during 1960 and two were transferred from the general enrolment. Membership was reduced by eleven owing to deaths, resignations and transfers leaving the total membership at the end of the year at 222.

## Activities During 1960.

Nine General Meetings and one Special Meeting were held during the year at which the following papers were presented:—

*General Meetings*:

26th February: "Hydro-Electric Power Development in Tasmania—Today and Tomorrow", by Mr. R. M. H. Garvie, B.Sc., M.I.C.E., M.I.E. Aust.

22nd March: "John Helder Wedge", by G. H. Stancombe.

22nd April: "The Endemic Flora of Tasmania", by Mr. H. J. King.

10th June: "Hobart—Now and Then", by E. R. Pretyman.

4th August: "Mutation and Selection in Man", by Professor A. M. Clark, M.Sc., Ph. D.

9th September: "Scenery in Canada", by Mr. M. S. R. Sharland.

28th October: "Hooker, Gunn and the Centenary of *Flora Tasmaniae*", by Professor H. N. Barber, M.A., Ph.D.

11th November: "Early Australian Jewry", by Dr. G. F. J. Bergman, D.Econ.

16th December: Members' Evening.

(1) "The Development of an Egg", by Mr. H. J. King.
(2) "The Merino in Spain", by Mr. G. H. Stancombe.
(3) "Flowers in Britain", by Mr. S. V. Tilley.
(4) "Colour Changes in the Male Blue Wren", by Mr. J. R. Skemp, B.Sc.
(5) "The Western Mountains and their Flora", by Mr. N. R. Harvey.

The average attendance at meetings was 71 members.

## Special Meeting.

In commemoration of the Centenary of the formation of local military forces in Tasmania, a Special Meeting was held on 6th May, 1960 to which representatives from Tasmanian service and civic organizations were invited. A lecture entitled "The Military History of Tasmania—an outline of the period 1803—1903", was delivered by Brigadier E. M. Dollery, M.V.O., O.B.E., M.C.

In addition members of the Northern Branch have attended, as guests, two special meetings of the Royal Australian Chemical Institute which were addressed by Professor Sir Alexander Todd, F.R.S. and Associate Professor J. B. Polya, D.Sc.Tech., B.Sc.

## Excursions.

Three excursions were held:—

27th February: Hydro-Electric Commission installations, Poatina.
5th-7th March: North-West and West Coast, Tasmania.
23rd October: "Belle Vue" and "Clyne Vale", Epping.

The excursion to the West and North-West Coast was the most ambitious project of its kind which has yet been undertaken by the Branch. During three days, forty-nine members examined Tasmanian aboriginal deposits at Rocky Cape, Mount Cameron West, the Arthur River and Devonport and visited "Highfield" and other places of historic interest at Stanley.

Arising from discussions concerning the publication of the Journals of John Helder Wedge, the General Council resolved to establish a new series of Special Publications, of which the Wedge publication will be the first. This decision was received with appreciation by the Northern Branch Council and Members.

As previously, the Branch Council record their acknowledgment of the services provided by the Queen Victoria Museum toward the conduct of the activities of the Branch.

C. CRAIG, Chairman.

W. F. ELLIS, Hon. Secretary.

# CHROMOSOME COMPLIMENTS OF THE TASMANIAN REPRESENTATIVES OF THE GENUS BLECHNUM.

By

C. J. Quinn

*Department of Botany, University of Tasmania.**

(With 4 figures.)

## ABSTRACT

Within the Tasmanian representatives of the genus Blechnum there are two basic chromosome numbers of 28 and 33. All the Tasmanian species are diploid with the exception of B. *fluviatile* which is hexaploid. A morphological difference in the spores has been correlated with basic number. Evidence is put forward to suggest that the Tasmanian species B. *procerum* (Forst.) Swartz can no longer be regarded as conspecific with the New Zealand species at present known as B. *minor* (R.Br.) Cockayne.

## INTRODUCTION.

The genus Blechnum is represented in Tasmania by nine species, though one, B. *cartilagineum* Swartz, is of doubtful occurrence at the present day. Of the remaining eight species, six are clearly defined, viz., B. *fluviatile* (R.Br.) Lowe ex Salom., B. *lanceolatum* (R.Br.) Sturm, B. *nudum* (Labill.) Mett. ex Luerss., B. *patersonii* (R.Br.) Mett., B. *penna-marina* (Poir.) Kuhn. and B. *vulcanicum* (Blume) Kuhn., while the other two species, B. *minus* (R.Br.) Ettings and B. *procerum* (Forst.) Swartz, present what appears to be a continuous range of variation between two extreme forms to which the species names have been applied. The present work is a part of that undertaken in connection with a study of the variation existing in this complex, with a view to determining the causes of this variation and to solving the taxonomic problems which prevail.

A similar complex is reported from New Zealand, and the nomenclature of the two groups has become confused. The names used in this paper for the Tasmanian species are those published by Wakefield (1957). To avoid further confusion at this stage, both B. *minus* and B. *procerum* as understood in Tasmania are illustrated in Figs. 3 and 4.

## MATERIALS AND METHODS.

The haploid chromosome numbers have been determined for each of the eight species using iron-aceto-carmine squashes of the spore mother-cells according to the method described by Darlington and La Cour (1947). Mature spores from each species were stained in lacto-phenol aniline blue according to the method described by Harris (1955).

## OBSERVATIONS AND DISCUSSION.

The haploid chromosome complements are illustrated in Fig. 1, and a list of the chromosome numbers determined on the Tasmanian material is given in Table 1. It can be seen from this that there are the two unrelated basic numbers of 28 and 33 in the group. Chambers, in an unpublished survey of the New Zealand species, has found the same two basic numbers. The species he has examined include three also occurring in Tasmania. These are B. *lanceolatum*, B. *penna-marina* and B. *fluviatile* for which he reports n = 33. The chromosome numbers for the first two species are in agreement with those of the Tasmanian material.

In B. *fluviatile* Chambers also discovered a sub-alpine race for which n = 66. Although there was a tendency for the pinnae of the sub-alpine type to be more midely spaced along the rachis, it was impossible to separate the two on morphological grounds. The Tasmanian species has a chromosome number of n = 99, and appears to be identical with the New Zealand species both in morphology and in the characteristics of the spore.

Chambers also reported that a polyploid series based on the number 28 exists among the New Zealand representatives of the genus. In the absence of any evidence of cross polyploidy between the two series, it seems likely that there has been parallel evolution within the genus.

An attempt has been made to determine whether there are any morphological characters associated with the two different basic numbers. Fig. 2 illustrates the only difference which has so far been correlated with basic number. It can be seen that the spores of all species possess a perispore. However the spores are of two morphological types corresponding to the two cytological conditions. Spores of B. *lanceolatum*, B. *patersonii*, B. *penna-marina*, B. *vulcanicum* and B. *fluviatile*, belonging to plants characterised by the basic number 33, have a thick, smooth perispore of the same shape as the spore. Spores of B. *minus*, B. *nudum* and B. *procerum*, belonging to plants characterised by the basic number 28, have a thin, hyaline perispore bearing irregular crests.

* Present address: Department of Botany, University of Auckland, N.Z.

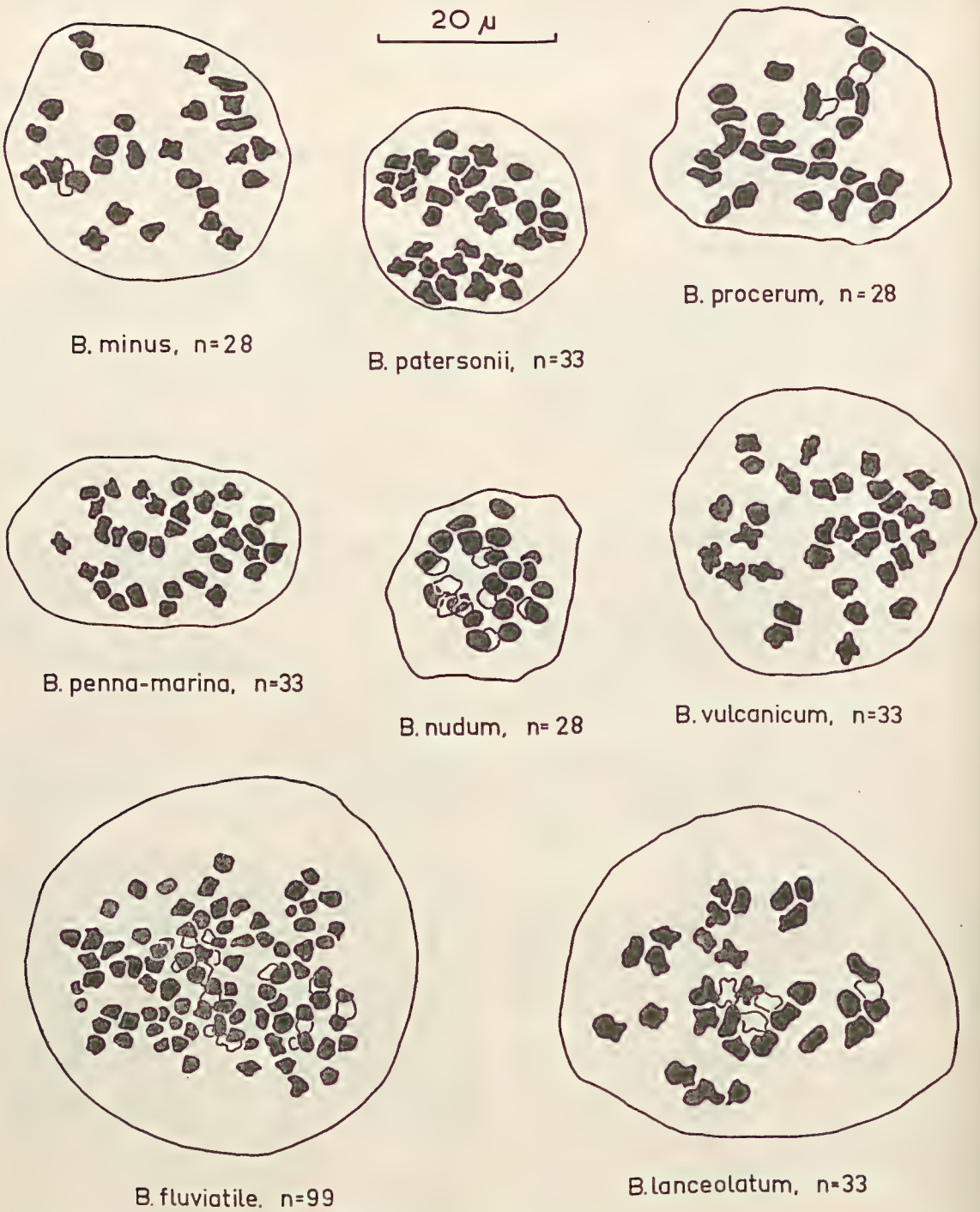


FIG. 1.—Haploid chromosome complements of the Tasmanian representatives of the genus Blechnum. Iron-aceto-carmine squashes of meiosis in the spore mother-cells.

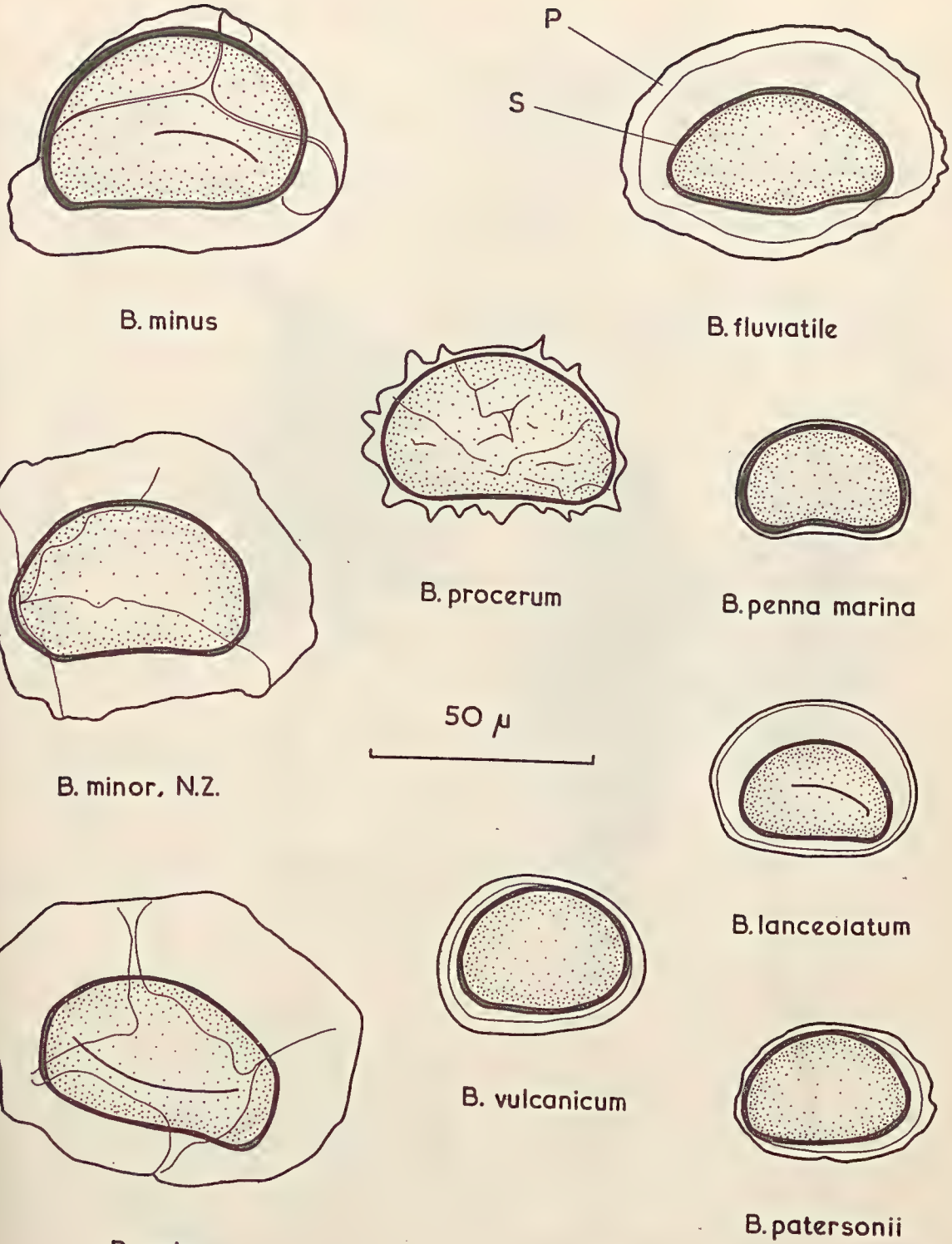


FIG. 2.—Drawings of spores of the Tasmanian representatives of the genus Blechnum and also of the New Zealand species B. minor, showing the nature of the perispore. P = perispore, S = spore wall. The spores of B. *minus*, B *nudum* and B. *procerum* possess a thin hyaline perispore bearing irregular cresets (crested, Table I). Those of B. *lanceolatum*, B. *patersonii*. B. *penna-marina*, B. *vulcanicum* and B. *fluviatile* possess a thick perispore of similar shape to the spore (smooth, Table I).

The New Zealand species B. *minor* (R.Br.) Cockayne has been generally regarded as conspecific with the Tasmanian species B. *procerum* (Forst.) Swartz.[1] However this seems very unlikely, since Chambers has recorded the chromosome number of B. *minor* as n = 56, and the spores, as shown in Fig. 2, have a perispore of similar structure to that seen in the Tasmanian species B. *nudum* and B. *minus*. This is of a totally different nature from the perispore seen in B. *procerum*. A closer morphological comparison of the two species is at present being undertaken.

Manton (1950) and Brownlie (1954) recorded a chromosome number of n = 34 for the European species B. *spicant* and the New Zealand species B. *penna-marina* and B. *vulcanicum* respectively. These numbers have not been found in Tasmanian material.

FIG. 3.—Typical fronds of the Tasmanian species *Blechnum minus* (R.Br.) Ettings. S, sterile frond; F, fertile frond. Base of the rachis in the fertile frond twisted so that the basal pinnae appear to be all on the one side.

FIG. 4.—Typical frond of the Tasmanian species *Blechnum procerum* (Forst.) Swartz. S, sterile frond; F, fertile frond.

## ACKNOWLEDGEMENTS.

I would like to record my thanks to the following: Professor H. N. Barber, of the Department of Botany, University of Tasmania, for his interest in this work and also for making available to me the facilities of his department; Dr. W. M. Curtis, also of the above department, under whose supervision this work was carried out, for her many helpful criticisms during the course of this work; Mr. T. C. Chambers, of the Department of Botany, University of Sydney, for permission to quote the results of his unpublished work on the New Zealand species of the genus Blechnum.

[1] Bentham (1878), P.373; Cheeseman (1906), P.981; Rodway 1903), P.283; Wakefield (1955), P.39.

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TABLE 1.

Chromosome numbers of the Tasmanian species of the genus Blechnum.

| Species. | Haploid Chromosome Number | Nature of Perispore | Source of Material |
|---|---|---|---|
| B. minus | 28 | crested | Ulverstone |
| B. nudum | 28 | crested | Forth Falls, National Park |
| B. procerum | 28 | crested | Arve Valley, Florentine Valley |
| B. lanceolatum | 33 | smooth | Hellyer Gorge, Mt. Wellington |
| B. patersonii | 33 | smooth | St. Columba Falls |
| B. penna-marina | 33 | smooth | Hellyer Gorge, Mt. Wellington |
| B. vulcanicum | 33 | smooth | Hellyer Gorge, Collinsvale |
| B. fluviatile | 99 | smooth | Hellyer Gorge, Collinsvale, Mt. Wellington |
| B. cartilaginium | .... | .... | Not collected |

# GRAVITY AND MAGNETIC OBSERVATIONS IN THE RED HILL AREA, SOUTHERN TASMANIA

By

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(With 4 text figures and 1 table)

## ABSTRACT

The results of reconnaissance gravity and magnetic traverses in the Red Hill area of Tasmania confirm the structure postulated as most likely on geological evidence. The granophyre which occurs in the higher parts of the Red Hill Dyke has arisen by differentiation of dolerite in situ, but the gravity work shows that it is unlikely that the dyke continues to a depth sufficient for all the granophyre to have been produced solely by differentiation of the vertical column of dolerite, so that some migration of acid residuum from the underlying dolerite sheet into the dyke has probably taken place.

The measurements illustrate how geophysical methods can be helpful in structural problems where dolerite has intruded less dense sediments, but show that caution is necessary when interpreting the results of magnetic surveys.

## INTRODUCTION

Recent detailed geological and petrological studies carried out on a large dyke-like intrusion of dolerite in the Red Hill area, south of Hobart, Tasmania (McDougall, 1960) have shown that a considerable volume of granophyre is associated with the dolerite. The granophyre occupies the highest structural parts of the Red Hill Dyke and has arisen by differentiation. The field data suggested that the dyke extends upwards for over 350 metres from a large underlying sheet of dolerite approximately 400 m in thickness. The volume of granophyre is considerably greater than could reasonably be expected to have formed from the column of dolerite available for differentiation. Two alternatives seem possible to explain the large volume of granophyre present in the dyke:—

1. That some of the acid residuum from the underlying dolerite sheet migrated into the dyke; or
2. That the dyke continues down through the floor of the underlying sheet to give a much greater volume of dolerite for differentiation.

In order to decide between the two alternative structures reconnaissance gravity and magnetic traverses were made over the area, the results of which are presented in this paper. In general these confirm the first structure as being the most probable interpretation of the geological observations. They almost certainly reject the alternative structure in which the dyke-like intrusion continues at depth, below the dolerite sheet. It is emphasised that the surveys were made in an attempt to determine the downward extension of the dyke and the analysis and discussion is mainly concerned with this.

Although in Figures 2-4, adjustments of the position of the underlying dolerite sheet have been made, for better agreement with the observations, we do not suggest that alternative structures are precluded. In fact, as the agreement between calculated and observed values in some places is not very good, it is probable that the actual structure is considerably more complicated.

Gravity surveys are particularly suited to the investigation of large-scale structural problems and are often used when searching for oil. In such areas the terrain is commonly flat giving ideal conditions for the detection of small anomalies of large areal extent. Dolerite intruding sediments presents problems more like those encountered when seeking metalliferous deposits; the dolerite intrudes sediments of somewhat lower density so that generally, positive gravity anomalies will normally occur over a limited area, which can be interpreted in terms of the geological structure. Surveys over intrusive bodies of this type have previously been made by Steenland and Woollard (1952), Romberg and Barnes (1954), and Greenwood and Lynch (1959).

Magnetic surveys often assist in determining the structures of basic igneous intrusions, as these rocks are normally very much more magnetic than the sediments. In the past, misleading results have sometimes been obtained because it has been assumed that the magnetisation of the rocks was entirely that due to induction in the earth's field, but it is now realized that most of these rocks possess permanent magnetisation, which is not necessarily in the present field direction. However, in this case, the direction and intensity of magnetisation and the susceptibility have been determined in another connection, so that we could hope to obtain helpful information from measurements of the vertical magnetic force.

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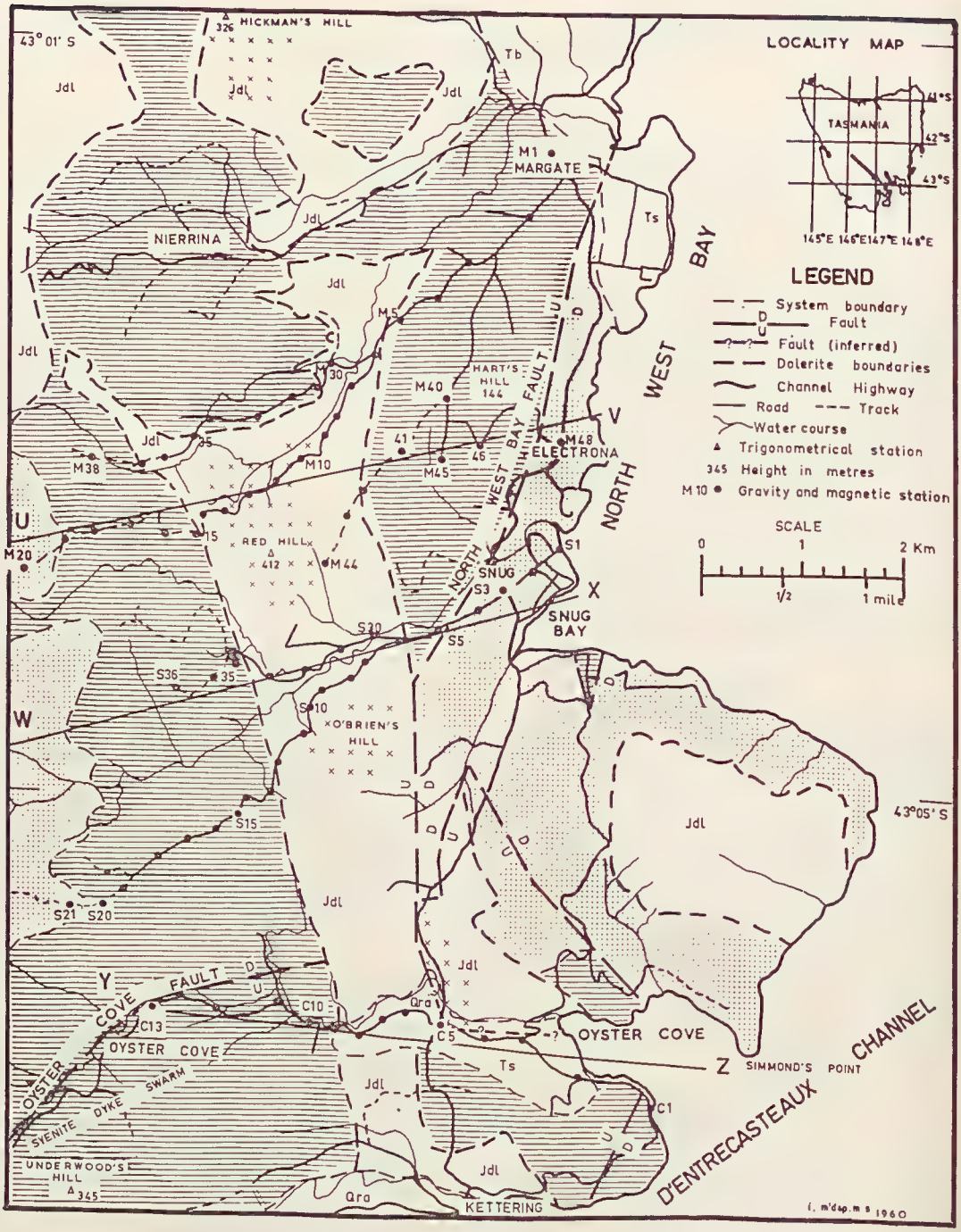



FIG. 1 (a)—Sketch map of Red Hill Area, Tasmania, showing simplified geology and stations at which observations were made.

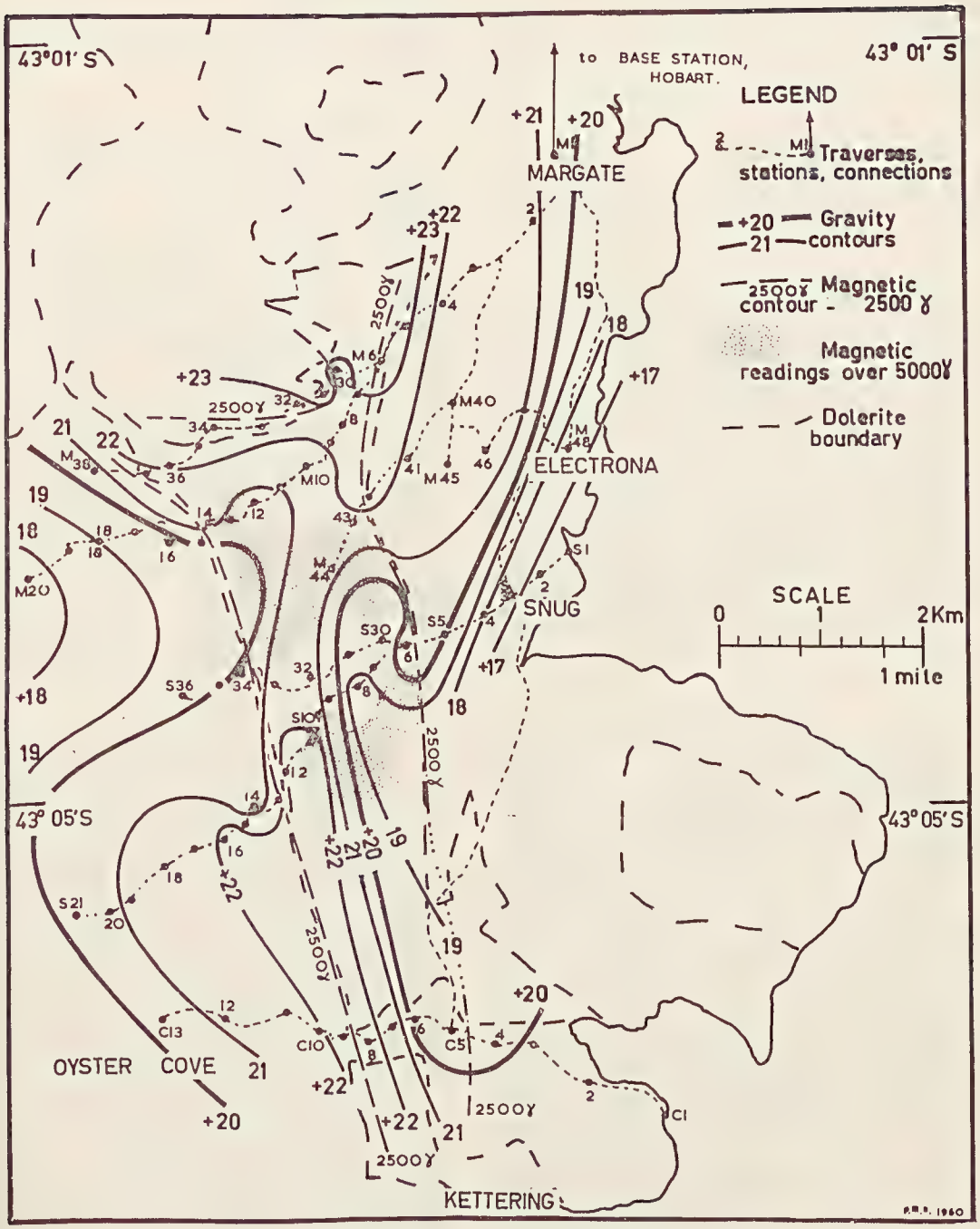



FIG. 1 (*b*)—Bouguer anomaly map (absolute values based on:—g = 979.9790 gals at Footscray, Victoria; elevation of Station S3 = 15.23m above MSL and S3 being at latitude 43° 03′ S), showing also magnetic anomalies greater than 2500γ and 5000γ (arbitrary datum).

## GEOLOGICAL SETTING

The Red Hill area is situated between about 15 and 30 kilometres south-west of Hobart in Southern Tasmania, and extends from Longley, below Mount Wellington, south to the shores of D'Entrecasteaux Channel. An area about 20 km long and 7 km wide has been mapped in order to elucidate the structural relationships between a large dolerite intrusion and the sediments. Geophysical surveys have been carried over the southern half of the area mapped (Fig. 1). The topographic relief is about 300 m and the rivers and creeks, which have dissected the region, have cut deep V-shaped valleys, but the hills are generally rounded in outline.

The geology of the area has been described by McDougall (1960), and only a short summary will be given here. The dolerite has intruded the gently-dipping Permian and Triassic sediments as a large sheet, approximately 400 m in thickness, and is transgressive upwards through the sedimentary sequence from east to west (Fig. 1).

In the northern part of the area this sheet is essentially concordant but to the south it passes abruptly into an almost vertical dyke-like body up to 1.5 km in width. This intrusion, the Red Hill Dyke, arises out of an underlying dolerite sheet which is continuous with that exposed in the northern part of the area. In the upper parts of the Red Hill Dyke, and in a similar structure at Hickman's Hill, granophyre is found associated with the dolerite. The field, petrological, and chemical data indicate that the granophyre has arisen by differentiation of the dolerite by a process of fractional crystallisation with the gravitational movement of phases.

## METHODS

Gravity observations were made with a Worden gravity meter (No. 61, scale factor = 0.08895 mgal/div.), magnetic measurements with a Schmidt-type Z-Variometer (Askania, No. 521615 scale factor 30 $\gamma$/div.) and the heights determined barometrically using an Askania Microbarometer. Measurements were made at the stations marked on Fig. 1 and form three main traverses across the dyke:—

1. Along Poverty Gully (Stns. M1-M20) (Subsidiary traverses M30-M39 and M40-M48).
2. Along Snug River (Stns. S1-S21) (Subsidiary, S30-S36).
3. Along the Oyster Cove-Cygnet Road (C1-C13).

Progress along each traverse was by means of loops, with a return to the initial station of the loop after about one hour; this took care of instrumental drift and also, in the case of magnetic and pressure measurements, of the diurnal variation. The gravity and elevation figures have been related to a bench mark, SPM 2683, in Snug township (Station S3 in Fig. 1). The height of this station has been measured by the Tasmanian Department of Lands and Surveys and the value of $g = 980.4683$ gals determined by us, by connecting with Hobart Airport (Stott, 1961). The gravity readings are absolute values based on $g = 979.9790$ gals at Footscray (Melbourne) and the elevations based on MSL Hobart. The magnetic values are based on an arbitrary datum. The observed gravity values are considered to be correct to 0.1 mgal and the height to about 4 m.

Rock density determinations were carried out on various sedimentary specimens and on the dolerite and related rocks by the method described by Jaeger and Green (1958).

## THE GEOPHYSICAL PROBLEM

The surveys aimed to investigate the extension at depth of the dolerite dyke which crops out at Red Hill. Surface mapping shows the sides of the dyke to be almost vertical and it is assumed that the dyke descends to some unknown depth with the same width. The intrusion can be regarded as a " two-dimensional " body, for which approximate formulae are available in the literature and which simplify the calculations necessary for computing the theoretical gravity anomaly due to an assumed cross-section. Similar formulae apply to the magnetic case. For parts of the intrusion the approximations are not applicable and an exact formula was used.

Gravity observations can provide information regarding sub-surface structure provided this involves horizontal variations in density. Without sufficient geological control, either from surface mapping or drilling, the results can only be interpreted qualitatively, since any potential distribution can be produced by an infinite variety of structures. Geological information provides boundary conditions which limit the range of possible solutions and it is, in any case, always possible to say whether or not the observations agree with any postulated structure. Similar remarks apply to magnetic surveys although sometimes more information can be obtained due to the existence of polarisation.

## REDUCTION OF RESULTS

Free air, Bouguer, and latitude corrections have been applied to the gravity observations (for details of these, see Nettleton, 1940). The density adopted for the Bouguer correction was 2.55 g/cc. The results are given in Table 1.

There are no contour maps of the area so that terrain corrections could not be made, although at some stations it is obvious that appreciable correction is necessary. It is estimated that the average slope is not more than 10° for a distance of perhaps 1½ kilometres and this involves a terrain correction of about two milligals (Sandberg, 1958). The change in the terrain correction between neighbouring stations would be much less than this. It is thought that a Precambrian (or early Palaeozoic) basement lies at about 600 m depth and this will add an additional uncertainty to the results. The main conclusions are clear in general outline, but the detailed picture could very well be modified with more gravity observations and especially with accurate survey information.

No terrain correction is applied to magnetic measurements. It is assumed that the diurnal variation is included in the drift recorded by repeat observations at the same site and is linear between observations. A check made of the records at Toolangi Observatory, Victoria, shows that no excessive disturbance occurred on any of the days observations were made.

| Station | Altitude (metres) | Observed gravity (mgal) | Free air* anomaly (mgal) | Bouguer* anomaly (mgal) |
|---|---|---|---|---|
| M1 .. | 25.0 | 980 465.89 | +22.78 | +20.11 |
| M2 .. | 55.3 | 461.10 | 27.31 | 21.22 |
| M3 .. | 49.2 | 463.25 | 26.72 | 21.47 |
| M4 .. | 73.1 | 459.02 | 29.55 | 21.75 |
| M5 .. | 100.1 | 455.61 | 34.32 | 23.64 |
| M6 .. | 100.2 | 455.50 | 34.10 | 23.41 |
| M7 .. | 125.8 | 450.42 | 36.60 | 23.18 |
| M8 .. | 138.3 | 447.12 | 37.02 | 22.27 |
| M9 .. | 146.3 | 445.23 | 37.46 | 21.85 |
| M10 .. | 171.2 | 440.08 | 39.84 | 21.57 |
| M11 .. | 193.0 | 435.15 | 41.35 | 20.75 |
| M12 .. | 216.4 | 430.27 | 43.69 | 20.60 |
| M13 .. | 244.7 | 425.06 | 47.04 | 20.94 |
| M14 .. | 267.2 | 421.14 | 50.09 | 21.58 |
| M15 .. | 302.1 | 412.62 | 52.19 | 19.95 |
| M16 .. | 322.5 | 407.83 | 53.68 | 19.27 |
| M17 .. | 355.5 | 401.18 | 57.22 | 19.29 |
| M18 .. | 367.5 | 398.56 | 58.30 | 19.09 |
| M19 .. | 380.7 | 395.33 | 59.14 | 18.52 |
| M20 .. | 502.2 | 370.18 | 71.19 | 17.61 |
| M21 .. | 631.6 | 343.50 | 84.59 | 17.20 |
| M22 .. | 654.3 | 341.72 | 90.51 | 20.70 |
| M30 .. | 130.6 | 448.95 | 36.78 | 22.85 |
| M31 .. | 162.7 | 442.95 | 40.53 | 23.17 |
| M32 .. | 190.8 | 437.01 | 43.26 | 22.90 |
| M33 .. | 209.4 | 432.61 | 44.45 | 22.11 |
| M34 .. | 235.6 | 427.50 | 47.43 | 22.29 |
| M35 .. | 247.6 | 425.45 | 48.92 | 22.51 |
| M36 .. | 259.4 | 422.51 | 49.49 | 21.81 |
| M37 .. | 267.9 | 420.89 | 50.49 | 21.91 |
| M38 .. | 272.1 | 419.51 | 50.41 | 21.38 |
| M39 .. | 290.1 | 415.05 | 51.36 | 20.40 |
| M40 .. | 147.3 | 444.41 | 37.10 | 21.38 |
| M41 .. | 220.3 | 429.73 | 44.65 | 21.14 |
| M42 .. | 269.5 | 421.32 | 51.11 | 22.36 |
| M43 .. | 275.5 | 419.78 | 50.98 | 21.58 |
| M44 .. | 283.8 | 417.69 | 51.29 | 21.01 |
| M45 .. | 130.5 | 448.24 | 35.30 | 21.37 |
| M46 .. | 101.8 | 454.01 | 32.36 | 21.50 |
| M47 .. | 58.2 | 462.18 | 27.38 | 21.17 |
| M48 .. | 20.8 | 466.57 | 19.78 | 17.56 |
| S1 .. | 0.7 | 980 470.18 | +16.44 | +16.36 |
| S2 .. | 5.9 | 469.36 | 17.07 | 16.44 |
| S3 .. | 15.23† | 468.28† | 18.71 | 17.08 |
| S4 .. | 31.8 | 466.12 | 21.51 | 18.12 |
| S5 .. | 39.5 | 466.70 | 24.31 | 20.10 |
| S6 .. | 68.2 | 461.00 | 27.33 | 20.05 |
| S7 .. | 112.6 | 451.30 | 31.22 | 19.21 |
| S8 .. | 145.5 | 444.51 | 34.52 | 19.00 |
| S9 .. | 180.9 | 438.77 | 39.58 | 20.28 |
| S10 .. | 206.4 | 435.30 | 43.83 | 21.80 |
| S11 .. | 236.4 | 429.87 | 47.50 | 22.28 |
| S12 .. | 262.3 | 424.84 | 50.33 | 22.34 |
| S13 .. | 272.6 | 422.19 | 50.54 | 21.45 |
| S14 .. | 273.6 | 421.53 | 50.17 | 20.98 |
| S15 .. | 286.8 | 419.24 | 51.83 | 21.23 |
| S16 .. | 305.6 | 415.59 | 54.80 | 22.30 |
| S17 .. | 339.7 | 408.37 | 58.11 | 21.87 |
| S18 .. | 371.8 | 401.60 | 61.10 | 21.43 |
| S19 .. | 384.8 | 399.21 | 62.45 | 21.39 |
| S20 .. | 417.5 | 392.18 | 65.50 | 20.95 |
| S21 .. | 460.5 | 382.88 | 69.31 | 20.17 |
| S30 .. | 50.2 | 462.21 | 23.12 | 17.77 |
| S31 .. | 105.3 | 451.95 | 29.72 | 18.49 |
| S32 .. | 86.3 | 454.52 | 26.29 | 17.08 |
| S33 .. | 133.7 | 447.08 | 42.19 | 19.20 |
| S34 .. | 217.4 | 429.82 | 51.09 | 18.99 |
| S35 .. | 267.2 | 419.68 | 47.27 | 18.76 |
| S36 .. | 288.8 | 415.56 | 49.80 | 18.99 |
| C1 .. | 1 5 | 980 478.74 | +20.87 | +20.71 |
| C2 .. | 6.4 | 477.73 | 21.52 | 20.84 |
| C3 .. | 11.4 | 476.00 | 21.63 | 20.42 |
| C4 .. | 25.0 | 472.79 | 22.62 | 19.95 |
| C5 .. | 35.9 | 469.85 | 23.21 | 19.38 |
| C6 .. | 57.4 | 465.91 | 26.04 | 19.92 |
| C7 .. | 58.1 | 467.39 | 27.74 | 21.54 |
| C8 .. | 52.8 | 469.25 | 27.81 | 22.18 |
| C9 .. | 56.2 | 469.09 | 28.71 | 22.71 |
| C10 .. | 67.9 | 465.88 | 29.26 | 22.01 |
| C11 .. | 83.9 | 462.18 | 30.65 | 21.70 |
| C12 .. | 94.1 | 459.67 | 31.14 | 21.10 |
| C13 .. | 87.0 | 451.82 | 21.24 | 11.96 |

* NOTE.—The latitudes for calculating the value of "$g$" from the International Gravity Formula were obtained by measurements on the original base map of Figure 1 (at four times the scale) assuming a value 43° 03'S for S3. The map and all records of the values have been destroyed by fire.

† Base Station.

In the case of both gravity and magnetic observations, no allowance has been made for regional gradient. The regional magnetic gradient is known to be about 9$\gamma$/km in a south-westerly direction. Effects due to this gradient will be insignificant compared with variations of some thousands of gammas found across the dyke. The regional gravity gradient is unknown.

## RESULTS

The results are given in Table 1 and the Bouguer anomalies presented as a contour map (Fig. 1).*

The pattern of anomalies is complex, but in general high gravity values occur over the exposed dolerite and the contours tend to follow the outcrop. Other features are the low values in the centre of the dyke over the granophyre, the high values west of the dyke in the region of stations S14-S16, and the offset of the maximum with respect to the outcrop along the Oyster Cove traverse. This asymmetry shows up elsewhere, being generally to the west of the dyke in the southern part of the area and to the east in the north, on each side of the fairly distinct division of the high anomalies in the Snug River region. A short traverse (S30-S36) was made on the north bank of Snug River, but perhaps owing to the steeper terrain and rapid variation in '$g$', the values are erratic and have been disregarded in preparing Fig. 1. However, the effect would have been to enhance the division and to produce two separate gravity highs. The data for stations S30-S36 are included in Table 1.

The average densities of the sediments are:—

| | |
|---|---|
| Ferntree Mudstone .... .... .... .... | 2.58 g/cc |
| Woodbridge Glacial Formation .... | 2.53 g/cc |
| Grange Mudstone .... .... .... .... .... | 2.54 g/cc |

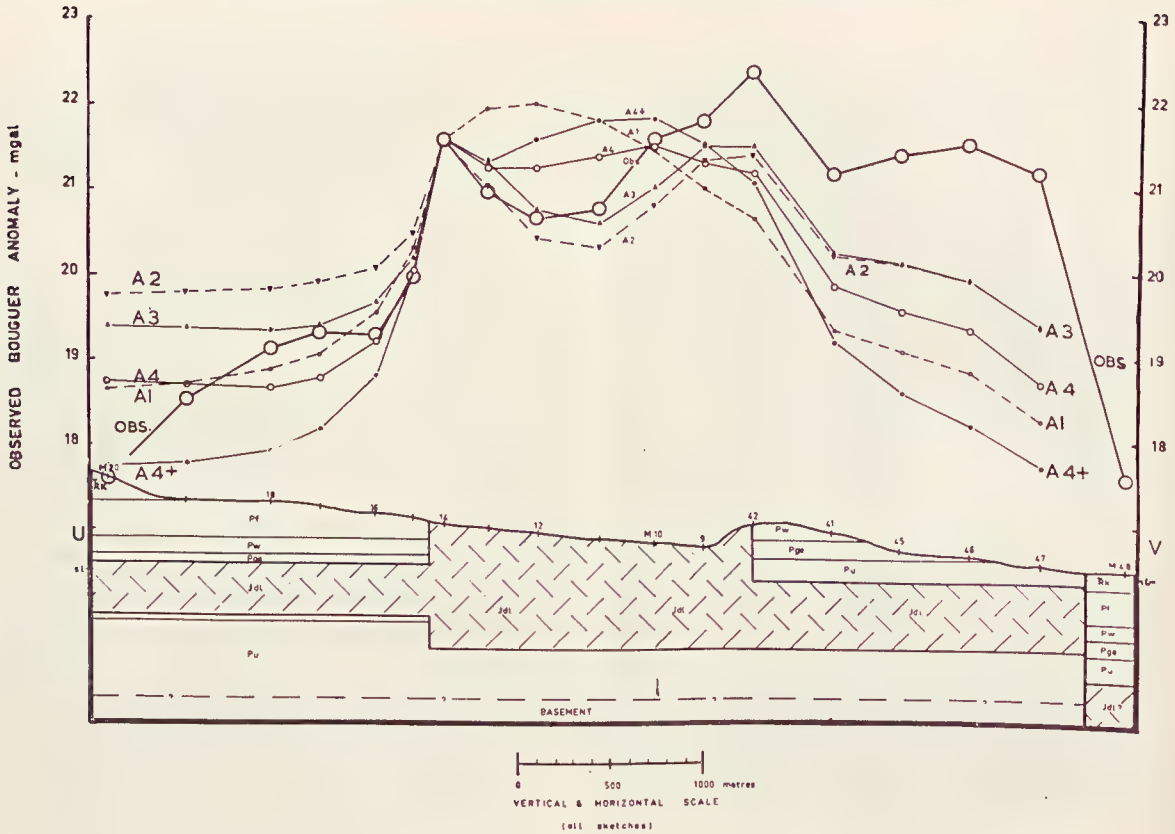
The density of the dolerite varies in a fairly regular manner and is dependent upon the position within the intrusion. From the values obtained the average density of the dolerite is about 2.85 g/cc, so that initially a density difference between dolerite and sediment was taken as 0.3 g/cc. in the gravity calculation. However, in the more detailed calculations is was necessary to make allowance for variation in density within the intrusion (see later).

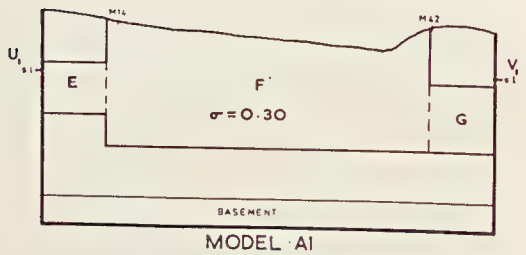
The magnetic results were much more irregular and it is possible only to show the results in a general way. Two contours labelled 2500 $\gamma$ (arbitrary datum) and 5000 $\gamma$ outline the outcrop of the dyke and of the granophyre (or more precisely, the higher portions of the dyke) within the dyke, respectively. The values of vertical magnetic intensity over the sediments range from 1000-2000 $\gamma$. It is known that the dolerite has a permanent magnetisation in an almost vertical direction (inclination about 80° to the west) and intensity usually about equal to the induced magnetisation.

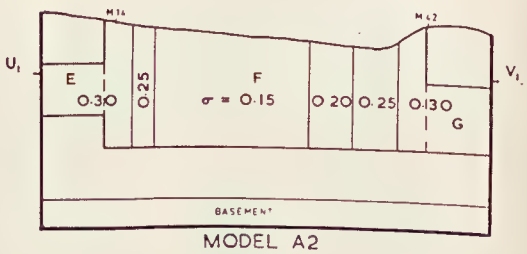
## DISCUSSION

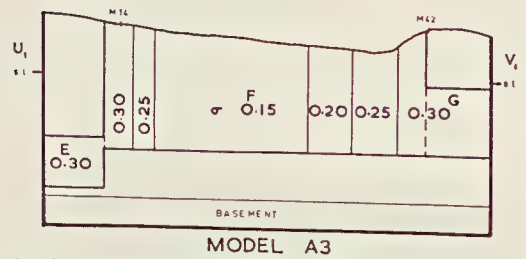
Three geological cross-sections have been prepared along the lines UV, WX, and YZ (Fig. 1), on to which the station positions have been projected and Bouguer anomaly profiles drawn using the values at each station. Initially, the

* The values in this paper were taken from the Table in McDougall (1960). Normally, we would have recalculated them from the primary data, but, as nearly all record of the original observations was destroyed in a recent fire at the University, this was not possible.



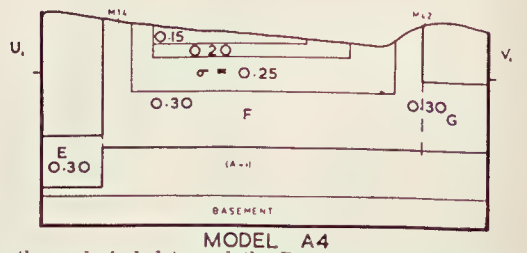




FIG. 2.—(*Top*) The Margate cross-section (UV) as interpreted from the geological data and the Bouguer anomaly values at Stations M19 - M20, M41, M42, and M45 - M48, projected on to line UV (Fig. 1). The calculated profiles are shown on the basis of models A1 to A4 (*below*) which show the sections $U_1 - V_1$ on the same scale. The portions of dolerite labelled E, F, and G, correspond in all sketches. Model A4+ is Model A4, with the dyke (F) continued downward for another 300 m. The figures $\sigma = 0.30$, &c., show the density difference assumed (in g/cc), between the dolerite and the sediments. In figures 2 - 4, it is to be understood that the calculated profiles are on an arbitrary datum, and can be moved upward or downward as required.

geology was that of the best interpretation of the field data, and theoretical anomalies calculated on the "two-dimensional body" basis (i.e., the dimension perpendicular to the plane of the section is large and can be taken as infinite). The cross-section is then adjusted consistent with the field evidence, to improve the fit of the observed and calculated values. Because the approximate formulae (Nettleton, 1942) are not suitablie for use with an outcropping dyke, an exact formula was used and the final calculations made on an electronic computer.*

### Section UV

Successive models used and the observed and calculated values are shown in Fig. 2. Model A1 was the original and A4 that finally adopted. Although the agreement is not good in the middle of the dyke it appears very unlikely that the dyke continues below the sheet except perhaps as a very narrow feeder dyke. The curve A4 + (Fig. 2) shows the effect of continuing the dyke downward another 300 m.

In this section, and to an even greater extent in WX, the main problem has been the apparent absence of mass in the middle of the dyke shown by the gravity observations. The depths of the lighter portions in model A4 have been made as great as possible consistent with the geological evidence. On geological grounds they would probably have been less, on geophysical grounds greater.

### Section WX

Fig. 3 shows the model, the calculated Bouguer anomaly profiles, and the observed gravity values reduced to sea level. Two calculated profiles are shown, with and without the downfaulted dolerite sheet east of North-West Bay Fault. The model is unrealistic in that the high density edge sections have been made wider than they appear on the ground and the lighter portion is unlikely to continue to the base of the sill.

$$* \Delta g = 0.667 \left\{ u \ln\left[(u^2+z^2)/(u^2+y^2)\right] - v \ln\left[(v^2+z^2)/(v^2+y^2)\right] + 2z\left[\tan^{-1}(u/z) - \tan^{-1}(v/z)\right] - 2y\left[\tan^{-1}(u/y) - \tan^{-1}(v/y)\right] \right\}$$

Where $\Delta g$ is the vertical attraction due to the rectangular body of density difference 0.1 g/cc, $u$ and $v$ the horizontal distance from the station to the nearer and farther (from the origin) vertical sides of the body respectively, $y$ and $z$ the vertical distances to the (horizontal) top and bottom of the body respectively; all distances in kilometres.

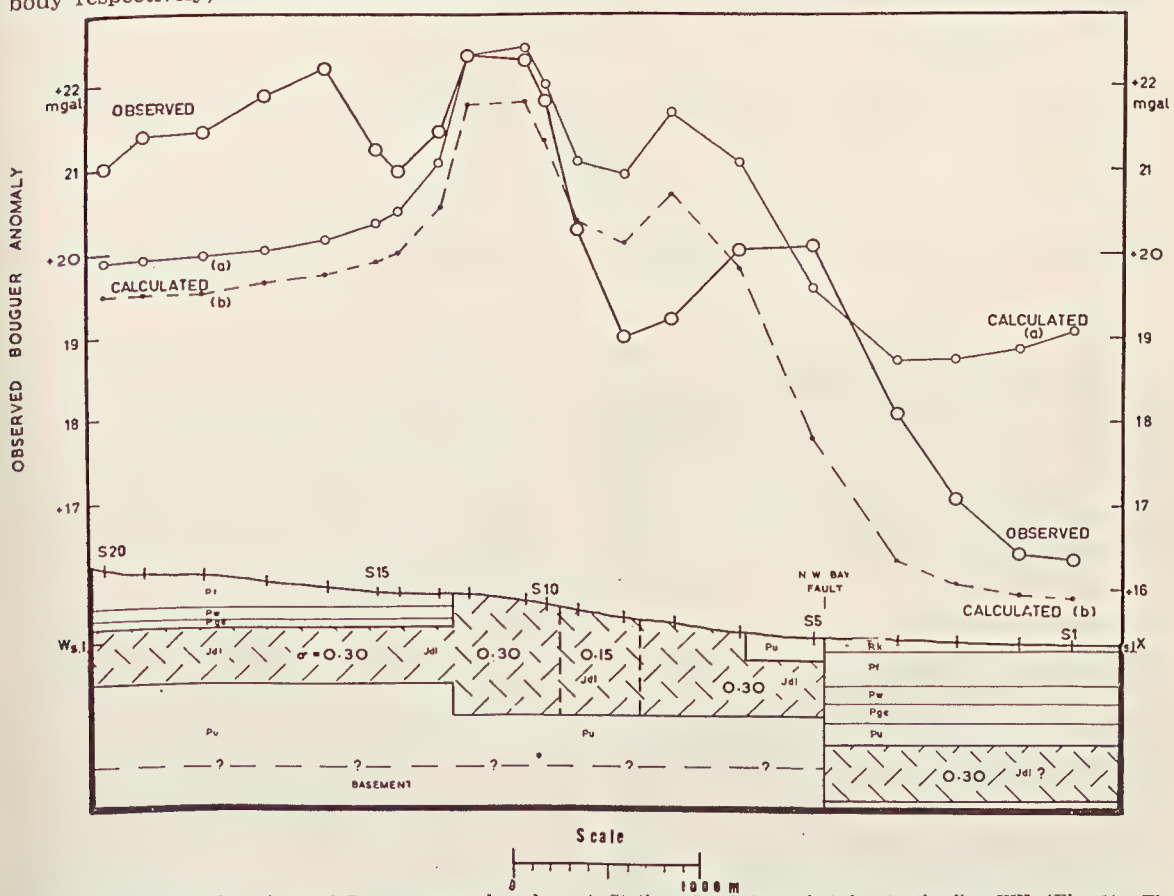



FIG. 3.—The geological section and Bouguer anomaly values at Stations S1 - S20, projected onto the line WX (Fig. 1) The calculated profiles are: (*a*) for the section as shown; (*b*) with the dolerite sill east of the N.W. Bay fault removed (or, which is equivalent, of placing it at a much greater depth). The figures $\sigma = 0.30$ and 0.15 are the density differences assumed (in g/cc) between the dolerite and the sediments.

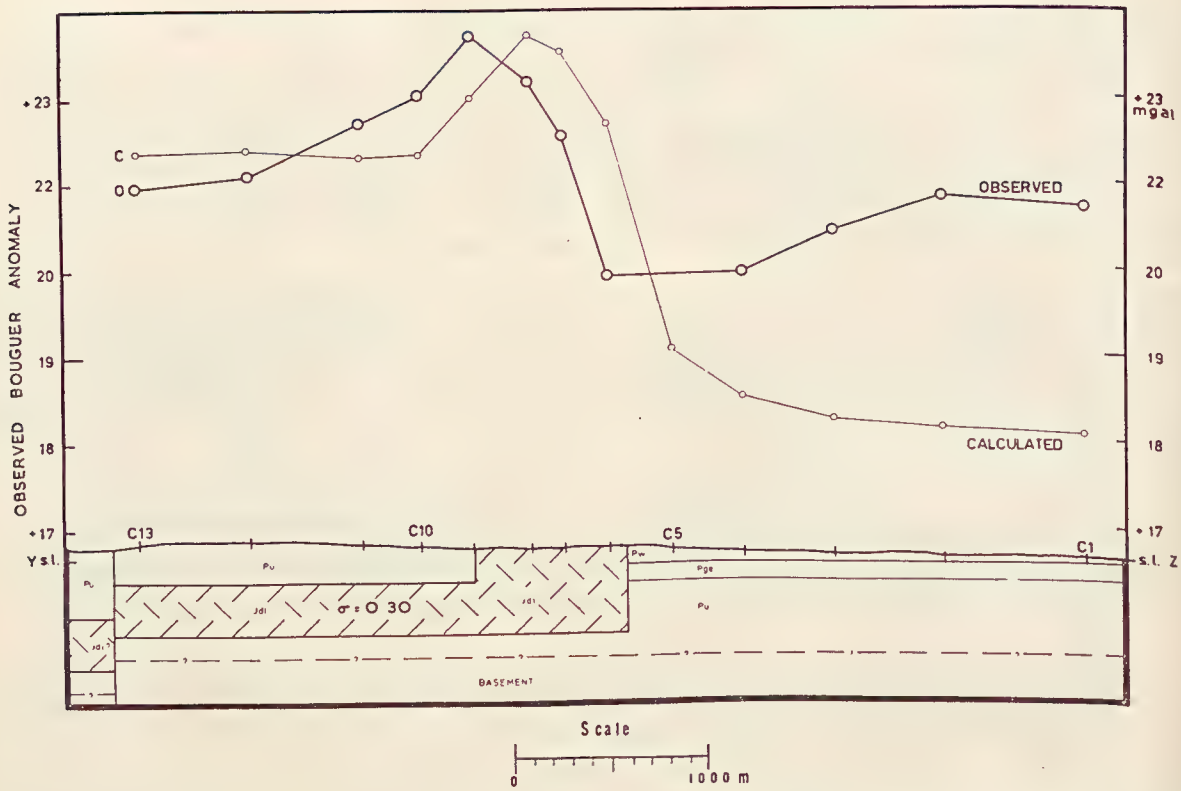



FIG. 4.—The geological section and Bouguer anomaly values at Stations C1-C13, projected on to the line YZ (Fig. 1). The calculated profile is based on a constant density difference between the dolerite and the sediments of 0.30 g/cc.

However, a more realistic cross-section would only make the already poor agreement worse and strengthens the view that there is no continuation of the dyke below the sheet. The peak at S15-S16 could be due to a hidden upward extension or transgressing of the sheet. The observed values agree better with there being no dolerite sill at the eastern end of the section. The calculated profile (*b*) would be essentially the same if the eastern dolerite were present, but at a much greater depth.

### Section YZ

The model and gravity values are shown in Fig. 4. No detailed analysis has been done on this section and a uniform density difference of 0.3 g/cc is assumed. The calculated and observed profiles agree well, compared with the others and the displacement of the peak of the observed values could be explained by the dyke dipping to the west, a possible situation on geological evidence.

There is a suggestion that on the two northerly traverses, the observed peaks are displaced to the east, but in view of the other discrepancies mentioned it is not a significant feature at present.

The magnetic results were disappointing. Strong positive anomalies occur in a narrow region over the margins of the Red Hill Dyke but the anomaly over the central part of the dyke is surprisingly small (Fig. 1). The directon of permanent remanent magnetisation of the dolerite at Red Hill has been measured and is quite uniform (near vertical), and is in accord with that found elsewhere in Tasmania (Jaeger and Joplin, 1955; Irving, 1956). However, as shown by Jaeger and Joplin, the intensities and susceptibilities of the dolerites vary markedly, even over small distances, and variation of this type would be reflected in the measurements of the vertical magnetic intensities across the Red Hill Dyke. Unfortunately, lack of detailed data on the variation in the intensities and susceptibilities of the Red Hill dolerite makes it extremely difficult to interpret the magnetic results. Similar observations have been made elsewhere in Tasmania (Weibenga and Polak, 1957; Weibenga, 1958) and in these cases rapid variations in the vertical force are characteristic. These can sometimes be interpreted in terms of shear zones and less commonly, in terms of thickness of dolerite present.

The geophysical observations show:—

1. Gravity measurements can be useful in structural problems of dolerite intrusions, particularly in the flatter areas.

2. Red Hill Dyke does not seem to extend much beyond 600 m below the surface.

3. Magnetic observations are not likely to be useful beyond determining the boundaries of dolerite intrusions hidden below soil or thin sedimentary cover.

## ACKNOWLEDGMENTS

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# THE GEOLOGY OF THE SOUTH ARM-SANDFORD AREA, TASMANIA

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(With 4 text figures.)

## ABSTRACT

Permian mudstones, sandstones and limestones are intruded by Jurassic dolerite in the form of gently transgressive sheets, sills and dykes. The sub-horizontal intrusions are restricted to the Grange Mudstone and show a pronounced development of coarse-grained dolerite near the top of the sill. Two Tertiary volcanic centres, one a breccia-filled vent, are situated near Tertiary faults, and folded ?Lower Tertiary limonitic sandstones and clays are recorded. Tertiary tensional faulting has tilted the strata to the west and caused the repetition of one stratigraphic horizon, the Malbina Siltstone and Sandstone. Necks, spits and coastal dunes are related to older, higher sea levels.

## INTRODUCTION

The area mapped consists of squares 5271, 5270, 5371 and 5370, the South Arm, Howrah, Ralphs Bay Canal and Clifton Beach squares which form the south-east part of the Hobart Sheet. Access to the area is readily available from the main South Arm road which is sealed as far as the Clifton Beach turnoff. The lower areas are used for orcharding or sheep grazing while the uncleared higher areas support an open sclerophyll eucalypt forest with a low scrub and bracken understory. The rainfall is a little lower than that of the Hobart area, 18-20 inches per annum.

Exposure is poor, except along the coastline where excellent sections are available. Mapping was carried out by walking boundaries, where this was practical, and pinpointing the outcrop on aerial photographs. The base map was constructed with the aid of a slotted template layout based on a limited amount of trigonometrical control. The compilation should not be regarded as entirely accurate in the Clifton Beach square as trigonometrical control was not available. The geological boundaries were transferred from the aerial photographs to the base map with a rectiplanigraph. Grid references are given as 6 figure coördinates referred to the State grid system. The map is included herewith as figure 1.

Specimens collected during field mapping are housed in the Geology Department, University of Tasmania, and the specimen numbers referred to in this paper are those of the catalogued specimens of the collection.

## PREVIOUS LITERATURE

Johnston (1888) referred to fossiliferous rocks near Pipe Clay Lagoon but the first regional survey of the area was that made by Nye (1924). Lewis (1946) mapped the area in more detail; unfortunately, the distribution of rock types on the map accompanying his text does not concur with his recorded field observations. Hosking and Hueber (1954) referred briefly to the Grange Mudstone at May Point, an occurrence which had been previously described by Jukes (1847) and Stephens (1900).

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## PHYSIOGRAPHY

The physiography is controlled by tilted fault blocks formed early in the Tertiary which strike approximately north and dip to the west at angles of up to 15°. The faults bounding these blocks provide planes of weakness along which later erosion has been directed.

Topographic relief is low with the exception of the range of hills above Rokeby, which rises to more than 800 feet. South of Ralphs Bay Canal, Mount Mather (581 feet) and Mount Augustus (535 feet) are more dissected remnants of this range. The tilted blocks of Permian sediments forming these mountains exhibit an almost cuesta-like structure, the westward slope approximating to a dip slope.

The present morphology of the area has been determined principally by the post-glacial drowning of the area and subsequent lowering of the sea level. Since the last glacial phase the coastline has been uplifted to the extent of 2 or 3 feet above the present H.W.M. and this former shoreline has been named the Milford level by Davies (1959). The peninsula is made up of several islands which are joined by deposits related to higher sea levels. The evolution of the Ralphs Bay neck has been described by

Davies (1959) and a similar mechanism of formation is proposed for the neck connecting the Sandford Peninsula to South Arm. Both erosional and depositional features are present; emerged shore platforms, abandoned cliffs, raised cobble, sand and shelly beaches, beach bordering dunes, stranded sea caves and cave deposits, spits and necks, all characteristic of a recently emerged coastline.

The Llanherne level (Davies, 1959) forms wavecut platforms and appears to be an erosional feature approximately 15 feet above H.W.M. It is possibly related to the last interglacial stage or a minor oscillation during the Würm glaciation. Earlier levels become progressively more dissected with elevation. Lewis (1946) recognised one level at 5-15 feet above sea level and another at between 50 and 60 feet. Other poorly developed levels are found at 100 and 180 feet with a better developed level at 250 feet. Submergence during interglacial stages has usually been brief. A deposit of marine sand at Mary Ann Bay contains a Pleistocene fauna 60 feet above the present high water mark.

Cliffs up to 150 feet in height and rising from a wavecut shore platform form most of the eastern seaboard. Wave action has been concentrated at right angles to the coast along minor faults and prominent joints, the closely spaced bedding planes and joints of the metamorphosed Grange Mudstone prevent extensive wave notching. The western sides of the peninsula have mature beaches in the protected bays and shore platforms developed on the Malbina Siltstone and Sandstone along exposed stretches.

Pipe Clay Lagoon at Cremorne is almost closed by a well developed, slightly arcuate sand-spit, post Milford in age, which has grown southwards from the Milford level shoreline. Tidal scour is responsible for the preservation of a narrow channel at the southern extremity. A shingle beach spit 4 feet in height is present on the eastern side of Gellibrand Point.

The coastal dunes are the result of a plentiful supply of sand from the beaches, the absence of obstacles in the sea (thus allowing the wind to blow more strongly than elsewhere) and the absence of vegetation in that part of the beach from which the sand is derived. The sand blown landwards from the frontal dune collects in dunes at right angles to the direction of the prevailing winds and thus a series of wavelike dunes is formed, separated by relatively flat-floored troughs. The parallel sets of coastal dunes produced in this manner are clearly demonstrated along Hope Beach, Clifton Beach, Opossum Bay and Half Moon Bay. Such dunes are characterised by an asymmetrical cross-section and cross bedding with a steep leeward slope which corresponds to the angle of rest of the sands. In the case of the dunes of Hope Beach, the leeward slopes of which are fixed by vegitation, the angle of rest is 40°. The angle of rest for dry unfixed sand of the same particle size as that in the ridges near Hope Beach is approximately 32°.

Most of the dunes which have migrated inland are now fossil dunes and contain an abundance of calcified roots and stems. These dunes are now perched and deprived of a supply of sand. The oldest dunes, i.e., those furthest inland and with the highest elevation, have almost lost their dune-like character and only in artificial exposures, such as present day sand pits, can cross bedding be recognised. Where the dunes have reached a degree of stability, a bed of podsolized sandstone (dark brown in colour) is commonly developed, and may be seen at the base of most sand excavations. The sand deposits are not worked below this resistant layer which assists materially in the stabilisation of the dunes.

Hope Beach and Clifton Beach slope towards the sea at angles of up to 10°, the steepness of the strand plain being due in part to the exposed nature of the beaches. Storm waves commonly produce "nips" in the poorly consolidated beach sands. Behind the necks a shallow lagoon is formed and commonly a salt marsh is found in this position, e.g. the marshes south of Ralphs Bay Canal.

Away from the sore platforms and cliffs, only the massive pebbly sandstones of the lower Malbina Siltstone and Sandstone outcrop at all strongly to form low cliffs. Sandstone beds in the Ferntree Formation outcrop as benches, and talus from these beds covers the shaly mudstone beds. In a similar manner, the upper mudstone member of the Malbina Siltstone and Sandstone is often covered with scree from the Risdon Sandstone. Inland the Grange Mudstone outcrops very poorly; one band more resistant than others is the zone of *Thamnopora* and *Cladochonus* 65 feet below the top of the formation. Fine cliff exposures of Grange Mudstone are found at Cape Deslacs, May Point and to the east of Single Hill.

Much of the area is covered by an extensive and often deep sandy soil and inland the dolerite is weathered deeply, especially on Droughty Point, where local run-off after heavy rain produces narrow steep-sided gullies. Terracettes due to minor soil slip on the steep sides of dolerite hills are common. More extensive landslips are found in the basalt soil near Cape Contrariety. The Clarence Rivulet is the only prominent drainage channel. Its course has been largely determined by the eastern edge of the Rokeby basalt, but the stream is now cut largely in its own gravels. During the summer the rivulet degenerates into a series of stagnant pools. The run-off in other parts of the area goes directly to the sea or into a chain of lagoons along the low-lying central portion of the Sandford Peninsula.

## STRATIGRAPHY

### Permian System

The Permian System in this area contains four formations, Grange Mudstone, Malbina Siltstone and Sandstone, Risdon Sandstone and Ferntree Mudstone. A complete section is not available and neither the base of the Grange Mudstone nor the top of the Ferntree Mudstone is exposed.

#### Grange Mudstone.

This formation consists of at least 150 feet of richly fossiliferous mudstone, siltstone, limestone and dolomite, with thin lenses of sandstone and granule conglomerate. It is the uppermost formation of the Cascades Group (Banks and Hale, 1957)

in the Hobart area, and is overlain with a slight erosional break by the basal member of the Malbina Siltstone and Sandstone.

At the base of the measured section at Cape Deslacs (see Brill, 1956) is an impure dolomite, light green to grey in colour which contains thin bands of dark green diopside due to contact metamorphism. Twenty feet above sea-level granule conglomerates and pebbly siltstones predominate and a thin layer of recrystallised calcite sheets is commonly found along the bedding planes. The next 16 feet are composed of coarse-grained sandstones interbedded with impure limestones, dolomites and pebbly mudstones. Large spiriferids occur as rolled fragments, the rocks are poorly-sorted and contain pebbles up to two inches in diameter. Massive, fossiliferous limestones and dolomites with mudstone intercalcations occupy the succeeding 24 feet. Pebbles become increasingly common towards the top of the formation and the remaining 27 feet are composed of pebbly siltstones, granule conglomerates, calcerenites and subordinate impure limestones and dolomites. Graded bedding is a common feature and fewer fossils are found in this part of the section.

A thin section cut from an arenaceous limestone 68 feet above sea level at Cape Deslacs contains 35% of sand grade, subangular to rounded quartz particles of up to 4 mms. in diameter. The grains are separated by irregular patches of recrystallised calcite. A few fragments of prehnite are present, but most of the matrix is made up of very fine calcite, the individual grains being so small that the slide is opaque. Grains of zircon and small laths of andesine are also present.

North of Ralphs Bay Canal, on the western shore of Ralphs Bay, another section of the upper part of the Grange Mudstone is exposed. This has been measured in detail and may be correlated with the section at Cape Deslacs. The base of the section is covered by a shingle beach in which fragments of mudstone containing *Cladochonus* are present. The bottom 30 feet of the section is composed of alternating pebbly and rather fissile mudstones, with subordinate thin bands of bryozoal calcarenites and spiriferid calcirudites. This is overlain by 5 feet of slightly argillaceous limestone containing abundant *Strophalosia jukesi*, fenestellids and stenoporids. As at Cape Deslacs, the limestone underlies sparsely fossiliferous mudstone, with pebbles becoming increasingly common towards the base of the Malbina Siltstone and Sandstone, some beds having distinct graded bedding.

On the shoreline of Ralphs Bay beneath Mt. Mather a similar section is exposed and a zone of *Cladochonus* and *Thamnopora* is also present at the southern end of the hills behind Rokeby (317178), 65 feet below the Malbina Siltstone and Sandstone, where it is associated with *Schuchertella*. The *Cladochonus-Thamnopora* zone is 68 feet below the base of the Malbina Siltstone on Maria Island (pers. comm. M. R. Banks). Other fossils include *Polypora woodsi, Fenestella dispersa, Stenopora crinita, Strophalosia cf. clarkei* and *Strophalosia typica*.

At 341103, Grange Mudstone is well exposed in a P.W.D. quarry as a fossiliferous mottled limy mudstone with dolomitic bands. As in the case with every outcrop in this area the Grange Mudstone has been affected by the intrusion of Jurassic dolerite.

**Metamorphism of the Grange Mudstone.**

Where the Grange Mudstone is intruded by dolerite, the contact metamorphic effects are considerable. Silicification commonly extends for as much as 100 feet from the point of intrusion, and contact metamorphism is most pronounced in the calcareous beds. The rock immediately adjacent to the dolerite in the case of a sill, e.g. north of Cape Deslacs, is either fissile and heavily weathered or hardened and very closely jointed. Some specimens from the contact zone contain prisms of pale green wollastonite and coarsely recrystallised calcite. At May Point impure limestones are interbedded with mudstones and near the margin of the transgressive dolerite the argillaceous limestone is dark green in colour and recrystallised.

Thin section 1094, a dark green hornfels collected within one foot of the contact, contains 40% of recrystallised calcium carbonate, 10% of subangular quartz fragments, 20% of clay material and 30% of small green granules with high relief, which are probably diopside. The matrix is an intimate mixture of recrystallised calcite and clay flakes with a few well-rounded grains of zircon and needles of apatite. Lamellar calcite crystals form veins from 0.1 to 0.5 mms. in width. The rocks retain a clastic texture microscopically, although in the hand specimen they appear to be recrystallised.

**Malbina Siltstone and Sandstone.**

The Malbina Siltstone and Sandstone formation consists of at least 280 feet of coarse sandstone, granule conglomerate, pebbly mudstone and siltstone which is correlated with a type section measured by Messrs. M. R. Banks and D. E. Read (see Banks and Read this volume) during 1959 near Jarvis Creek in the Claremont square. The Malbina Siltstone and Sandstone underlies the Risdon Sandstone and overlies the Grange Mudstone and the formation replaces the undefined term "Woodbridge Glacial Formation".

The basal member "A" overlies the Grange Mudstone with an erosional break or diastem owing to current scour. This is especially marked in the basal beds at Cape Deslacs and at 314174. Immediately above the base, member "A" contains 5-10 feet of poorly-sorted conglomerate and pebbly sandstone grading into a pebbly siltstone. Angular quartzite and granite boulders of up to 15 cms. in diameter are relatively common and the matrix is of fine sand to clay grade. The rock is thick-bedded, cream or grey in colour, tough and shows a rhythmic graded bedding which has been described by Brill (1956).

Rock fragments are composed almost entirely of quartzite and granite with subordinate angular fragments of slate, phyllite and quartz muscovite schist.

In thin section 1082, 80% of angular to subrounded quartz grains with a mean diameter of 0.45 mms. are present. Fresh plagioclase fragments are rare. The presence of a bent fragment of feldspar and quartz showing undulose extinction

indicates a metamorphic source. The matrix (12%) is composed of silt grade quartz, chlorite, limonite and a small amount of micaceous clay grade material with zircon and rutile as accessory minerals. Rock fragments, mainly quartz mica schist and micaceous quartzite, constitute 5% of the rock. Small granules and powdery aggregates of limonite are concentrated around the edges of quartz grains. Where regrowth has occurred, the original outline is shown as a ring of inclusions of fine ilmenite. The texture is mosaic away from the larger patches of matrix.

Large poorly preserved casts and moulds of spiriferids are common, *Ingelarella* and *" Spirifer " avicula* have been identified. A peculiar feature of both this and the overlying member is that the spiriferids are aligned parallel to the bedding. Pebbles of the underlying Grange Mudstone are confined to the basal conglomerate.

At 348059 the basal member is exposed on top of a small hill. Here the rock is a poorly-sorted subgreywacke sandstone containing approximately 25% of highly angular quartzite fragments in a slightly calcareous matrix of sand to silt grade. Similar exposures are found on the shoreline beneath Mt. Mather and north of Ralphs Bay Canal.

Graded bedding, although imperfect, is present in this member and has been recognised in each of the above mentioned localities. A typical sedimentation unit consists of a poorly-sorted granule conglomerate at the base which grades upward within approximately 9 inches into a siltstone which contains less than 5% of angular quartz fragments. There are very few fenestellids in this member and it is rare to find complete shells of the brachiopods. These factors suggest that the depositional area was one of considerable turbulence.

The remainder of member " A " consists of approximately 55 feet of fossiliferous pebbly siltstone alternating with sandstone and subordinate bands of granule conglomerate. This member commences with a band of granule conglomerate three feet thick resting on an irregular bedding plane. *Ingelarella* and *" Spirifer " avicula* are common while *Schuchertella, Stenopora crinita, Peruvispira* and crinoid stems are present. Fenestellids and stenoporids as extended mats are almost entirely restricted to the siltstones and mudstones, although broken fragments are found in the coarser bands. Graded beds are present in this member and a small amount of load casting appears to have taken place at the base of some of the coarser beds.

Member " B " comprises approximately 125 feet of massive sandstone and siltstone, cream or white in colour and poorly fossiliferous, which contain fewer pebbles than the underlying member. This member forms most of the shoreline of the peninsula and commences with a pebbly sandstone 3 feet thick, which is overlain by massive sandstone beds with subordinate siltstone layers. The mean grain size decreases towards the top of the member where fissile and non-fissile siltstones alternate. Pebbles of quartzite, phyllite and granite as large as four inches in diameter are scattered through this member. The matrix is composed of clay minerals, chlorite and quartz, and is of clay grade. The sorting is poor and lenses of sandstone occur in many places.

The pebbles occur in irregular patches and may best be described as " erratics '. Evidence that the pebbles have in some cases been dropped into the mud on the sea floor is provided at 306155, where an elongate pebble with the long axis vertical has broken fine cross laminations and bent those at the base of the pebble. Similar rocks occur at many places on the peninsula, but correlation can be made only on lithological similarity unless the stratigraphic position can be ascertained.

At 313069 approximately 15 feet of pebbly sandstone overlie a pebbly mudstone and are overlain by two feet of very pebbly coarse mudstone containing large angular pebbles of quartzite and slate. This massive sandstone unit is recognised in several localities, but is very variable in character and in thickness. Such exposures are referred to as member " C ", but it is not clear that all such exposures can be correlated on the evidence available.

The top of the section consists of approximately 75 feet of poorly exposed fissile siltstone with subordinate sandstone and limestone bands. Poor exposures of this member are present near the top of Mt. Mather, and at 271185 sparsely fossiliferous mudstones are exposed which contain poorly preserved spiriferids and pelecypods. This exposure is probably close to the top of the formation. The *Terrakea* zone recorded in the Hobart area beneath the Risdon Sandstone is present at only one locality, 345002, where it is poorly exposed.

There are three horizons in this formation in which pebbly sandstone like the Risdon Sandstone outcrop. The first is approximately 10 feet above the base, the second approximately 60 feet above the base, and the third, approximately 185 feet above the base. The uppermost one is easily mistaken for the Risdon Sandstone if the outcrop is poor.

Erratics as much as four feet in width are exposed at 264165 on the Tranmere shore platform. This exposure is unusual in that sedimentary rocks are present as erratics in addition to the normal types from an igneous and metamorphic terrain. Angular fragments of mudstone, siltstone and sandstone comprise 40% of the surface area of a rock face about 3 feet square. The fragments have straight edges in many cases and appear to have undergone very little transport. In the same bed, there is a concentration of quartzite and granite boulders as much as 30 cms. in diameter, with a rounded schist fragment 25 cms. x 15 cms. and a boulder of grey granite 100 cms x 80 cms. The largest erratic is a subrounded boulder of quartz sandstone 120 cms. x 80 cms., which contains mica and a small amount of feldspar, is veined with quartz and shows faint cross-bedding.

At the western end of Hope Beach, 267006, a massive sandstone 16 feet 6 inches in thickness overlies fossiliferous mudstone and pebbly coarse mudstones of at least 50 feet in thickness which appear to be similar to the basal part of the Malbina Siltstone and Sandstone. Two bands, 3 feet 6 inches and 14 feet 9 inches beneath the base of the sandstone, are extremely fossiliferous and contain abundant poorly preserved impressions of a spinose productid.

The basal unit of the massive sandstone is 1 foot in thickness, is graded and has an irregular bottom contact with the underlying fossiliferous mudstone and contains more than 80% of angular pebbles of both quartzite and fenestellid mudstone as much as 15 cms. long. The matrix is of sand grade, the rock is poorly sorted and best described as a petromict paraconglomerate (Pettijohn, 1957). This unit is succeeded by a massive, poorly-sorted pebbly sandstone, which contains pebbly layers at intervals of approximately one foot and, at the base, large subangular pebbles of quartzite and granite. The massive sandstone is overlain by a pebbly siltstone containing abundant small calcareous tubes about 2 mms. in diameter. It is thought that this member is the basal part of member " C " and that this member varies considerably in both pebble content and thickness.

Irregular markings at least 35 cms. in length and 2 cms. in diameter occur on the undersurface of several beds of fine sandstone above the massive sandstone at 267006 and on at least one horizon below it. The best example is found on a block which has fallen from the cliffs, and on the bedding face more than two hundred separate markings, both straight and curved, are present. The most probable explanation is that worm trails left in a soft mud were later filled by fine sandstone. The markings are apparently continuous with the sandstone of the overlying bed and show no structures which allow identification of the parent organism.

A dark grey, coquinoid limestone is exposed approximately 160 feet above the base of the formation at 313193. Half the fossil fragments are of productid brachiopods while bryozoans, foraminifera, pelecypods and productid spines are present. The shell fragments are resorbed in some cases and are set in a matrix of recrystallised sparry calcite combined with smaller angular grains of silt to clay grade. Accessory minerals include plagioclase, ilmenite, muscovite and chlorite.

The Malbina Siltstone and Sandstone is a sequence of interbedded siltstone, pebbly siltstone, sandstone, granule conglomerate and rare limestone. Many of the sandstones are lithic greywackes (Pettijohn 1957), subgreywackes or protoquartzites as the labile fraction varies from less than 3% to as much as 30%. Rock fragments are more common than feldspars, but the presence of a few fresh feldspar phenoclasts suggests a degree of mineralogical immaturity. The finer-grained siltstones, often relatively well-laminated, contain less than 3% of phenoclasts which are rarely of greater than sand dimensions; quantitatively, these occupy over half the section and must be considered as the dominant rock type.

Almost all the large pebbles found in the Malbina Siltstone and Sandstone have come from a terrain of metamorphic and acid igneous rocks. The fragments have suffered little fluviatile transport and the relief of the source area must have been such that river transport was at a minimum.

The depositional area at this time was probably that of a shelf covered by silt. Currents appear to have had little effect and conditions were favourable for the growth of bryozoans. Deposition appears to have taken place below wave base, as the matrix of many of the rocks consists of material from both the silt and clay grades and is not well-sorted.

When sufficient gravel had accumulated close to the shoreline, where relatively robust spiriferids were common, a slight tectonic disturbance or even a climatic change would be sufficient to spread the gravels over the sea floor in the form of a " slurry " or tubidity current. Periodic disturbances of this nature would be competent to produce the graded bedding of member " A ". A small amount of post-depositional loadcasting took place before lithification.

A change in sedimentation conditions is shown by unit " B " and conditions were unfavourable for the development of marine life. The large erratics often seen in otherwise well-sorted siltstone are concentrated in patches and the most plausible explanation of this observation involves rafting, probably by ice. These deposits have none of the secondary characteristics of large scale turbidite sequence such as abundant slump structures.

The incidence of erratics decreases upwards; member " C " represents a temporary return to the deposition of a pebbly sandstone but silt deposition continued under conditions increasingly favourable to life towards the top of the sequence. At this stage the relief of the land surface had become lower and the supply of angular fragments had diminished, but periodic occurrences of Risdon-type sandstone through the Ferntree Mudstone suggest that stability was not completely attained.

**Risdon Sandstone**

The Risdon Sandstone outcrops strongly between the Malbina Siltstone and Sandstone, which underlies it, and the overlying Ferntree Mudstone. The formation is approximately 15 feet thick, and is best exposed as a bench at the summit of Mt. Mather, 317148, and at 313182.

The basal member is a conglomerate, approximately 1 foot thick and poorly exposed. This is overlain by a thick-bedded pebbly sandstone which is poorly-sorted and weathers to a dark brown to grey-black colour. The number of pebbles decreases towards the top of the bed and at the top, the formation is well-sorted sandstone. A thin-section (1056) from the centre of the formation contains 10% of angular quartz and quartzite pebbles with a small amount of twinned plagioclase and microcline. The matrix consists almost entirely of quartz and small rock fragments in the 0.5—1 mm. size grade. A few quartz fragments show undulose extinction. Some quartz grains show sutured boundaries, forming a patchy mosaic texture. The matrix is cemented by a small amount (1%) of ferruginous clay.

Sutured boundaries in a relatively clean sandstone are probably due to the absence of interstitial clay with its cushioning effect during diagenesis. There is no suggestion that thermal metamorphic recrystallisation has taken place.

**Ferntree Mudstone**

This formation is conformably underlain by the Risdon Sandstone and underlies the Triassic rocks. The only large outcrop of Ferntree Mudstone is

at 313184 while Mt. Mather is capped by approximately 10 feet of mudstone overlying the Risdon Sandstone.

Lenses of poorly-sorted sandstone approximately five feet in thickness are present 20 feet and 100 feet above the base. Poorly-sorted siltstone bands contain up to 25% of angular quartz fragments of coarse-silt grade. The marix of the thin-bedded siltstone beds is made up of indeterminate rock fragments, cloudy feldspar and fine quartz particles of clay grade with small amounts of biotite and muscovite.

The sandstone bands are of fine to medium sand grade, poorly-sorted and pale cream in colour. Angular pebbles of quartzite and slate greater than 2 mms. diameter form 3-5% of these bands. The matrix is dominantly quartz with a small amount of feldspar and rock fragments, subangular in shape and of medium sand grade size. Only the lower 170 feet of this formation is exposed in the hills behind Rokeby, the section being terminated by a steep intrusive dolerite contact.

## TRIASSIC SYSTEM

A quartzose sandstone outcrops on the north-east tip of Betsey Island which is correlated on lithological grounds with the Knocklofty Formation of the Hobart area. Approximately 60 feet of clean, well-sorted sandstone are exposed; the bottom 25 feet are bedded at intervals of between three inches and one foot, extensively cross-bedded, and contain a carbonaceous pebbly band nine inches in thickness. Thirty-five feet of friable thick-bedded sandstone occur above this unit, medium yellow orange in colour on the weathered surface.

A thin-section (1055) contains quartz fragments of high sphericity ranging in size from 0.6 mms. to 0.025 mms. with a mean diameter of 0.3 mms. and 1% of indeterminate, sericitised rock fragments. The rocks dip to the west at an angle of 30° and near a fault contact against the dolerite a considerable drag dip is visible.

At 322194 is a small outcrop of a well-sorted quartz sandstone under a thick cover of Recent sands. Triassic sandstones outcrop just to the north of the Ralphs Bay Canal square along the road to Seven Mile Beach, and the outcrop at 322194 is probably the southward continuation of this down-faulted wedge of Triassic rocks.

## JURASSIC SYSTEM

### Dolerite

In several places on the Sandford Peninsula the tops of dolerite sills or gently shelving sheets of presumed Jurassic age (Hills and Carey, 1949) are exposed. In almost all exposures the dolerite is intrustive into the Grange Mudstone within 100 feet of the base of the Malbina Siltstone and Sandstone. Typical examples are Cape Deslacs, Single Hill, Roches Beach and Cape Contrariety. The pegmatitic zone is particularly well exposed and pegmatitic veins are common in the upper zone.

In hand specimen the fresh dolerite is even-grained, blue-grey in colour and of medium grain size. At an intrusive contact the dolerite became dark-grey to black in colour and fine-grained. The pegmatitic veins exposed in cliff sections may either be concordant with the top of the sill, as thin transgressive "dykes", or irregular schlieren of coarse-grained dolerite in relatively fine-grained material. The concordant veins are remarkably constant in thickness for several hundred yards with an average width of two feet, but thin rapidly at the extremities. The contact between the pegmatite veins and the normal dolerite is typically sharp at the base and a thin band of finer grain size and light colour may occur at the border of the vein.

The dolerite sills of this area differ from the sills hitherto described (Carey, S.W. (Edit.) Dolerite Symposium, July, 1958) in that the upper zone is less than 20 feet in thickness. A similar occurrence at 191017 (Kingborough Sheet) north of Piersons Point has been found by Mr. H. A. Bartlett.

The composition of the dolerite at a chilled margin is comparable to the Mount Wellington sill, containing 48% pyroxene, 45% plagioclase, 5% mesostasis and 2% iron ore. At the contact the texture is fine-grained, intergranular and porphyritic. Lathlike microphenocrysts of orthopyroxene, plagioclase and some clinopyroxene are common and slide 1000 contains a phenocryst of enstatite 0.7 mms. by 0.3 mms. in size. The groundmass is very fine-grained and consists of a small amount of quartz with small subhedral laths of twinned plagioclase, anhedral pyroxene and scattered granules of iron ore.

Away from the upper contact both the plagioclase and pyroxene increase rapidly in size and the texture becomes sub-ophitic. Some orthopyroxene remains but it is strongly corroded and is often rimmed by augite. In slide 1014 a phenocryst of secondary hypersthene is present. Pleichroic hornblende occurs as small prisms containing inclusions and often surrounds clinopyroxenes. Biotite and iron ore are scattered through the mesostasis and other accessory minerals include calcite, apatite, stilbite and prehnite.

The composition of the rocks in the pegmatitic zone is extremely variable and veins of pegmatitic material are found within 20 feet of the top of the sill north of Cape Deslacs. The pegmatitic zone proper extends well below this, as coarse-grained pegmatitic dolerite is exposed along the shoreline below Calvert's Hill.

In general, a high proportion of mesostasis is characteristic (13-37%), and in the slides counted the amount of plagioclase (34-51%) exceeds the amount of pyroxene (17-38%), while iron ore (0.6-5.6%) appears to be concentrated only in some specimens. The texture is hypautomorphic to automorphic granular with an intersertal groundmass. Laths of zoned plagioclase ($Ab_{50}$-$Ab_{45}$) of up to 5 mms. in length occur in a groundmass of low relief broken by rods, octahedra and anhedra of iron ore. Heavily chloritised primary orthopyroxene accounts for less than 2% of the pyroxene of slide 1003, 30 feet below the upper contact.

Both pigeonite and augite are present, uniaxial pigeonite is comparatively common and bladed pyroxenes as much as 11 cms. in length can be found at 386094. Some of the clinopyroxene is

altered to pleochroic chlorite. The large automorphic plagioclase laths are of zoned labradorite but some of the smaller subhedral laths are more sodic in composition ($Ab_{50}$-$Ab_{70}$). The mesostasis in the pegmatitic rocks is dominantly of two types, types 2 and 3 of Spry (1958), and contains quartz, orthoclase and some subhedral plagioclase which has a refractive index indicative of albite. The most common type of mesostasis is a coarse-grained quartz-orthoclase graphic intergrowth.

On the road to Clifton Beach at 343102 a plug of dark-coloured, fine-grained dolerite outcrops. This rock contains approximately 8% of primary enstatite which is rimmed by simply-twinned clinopyroxenes Euhedral radiating laths of plagioclase (30%) are intergrown in an ophitic texture. The mesostasis consists of anhedral orthoclase with small needles of quartz and apatite and irregular fragments of iron ore which are closely associated with both the altered borders of the primary orthopyroxene and the mesostasis which accounts for 28% of the rock, an anomalously high value.

A slide (1024) cut from a loose block on top of Betsey Island shows the considerable increase in iron in the end products of the magma. The texture is intergranular and the rock contains plagioclase (50%), pyrozene (20%), mesostasis (20%) and iron ore (10%). The plagioclase is zoned from $Ab_{40}$ to $Ab_{70}$ and occurs as subhedral, interpenetrating laths up to 1.25 mms. in length. Pyroxenes, both pigeonite and augite, of prismatic habit average 10 mms. in length and are commonly altered to a red iron oxide along cleavage cracks and rimmed by small flakes of green hornblende. The pale brown colour of the unaltered augite suggests that it may be a ferroaugite. The mesostasis is predominantly anhedral quartz and orthoclase, containing many small skeletal crystals of iron ore. In a small patch on the slide the mesostasis is composed of chlorite and iron ore in equal proportions.

At the junctions of the pegmatitic lenses and the host rock a thin white line may indicate that the high concentration of water and potash in the residual has been responsible for deuteric alteration. No feeder dykes for the pegmatitic lenses were seen. The residual material forming the mesostasis is often well crystallised. The occurrence of pegmatitic segregation so close to the top of a sill suggests the magma was at least partly liquid and it seems likely that the magma was still in the form of a crystal "mush" in order to allow stratiform segregations to develop.

TABLE 1.

| Slide | 1000 | 1001 | 1014 | 1002 | 1003 | 1004 | 1005 | 1006 | 1009 | 1012 | 1038 | 1015 | 1024 | 1007 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plagioclase | 45.3% | 35.0% | 46.3% | 31.5% | 40.1% | 47.5% | 34.8% | 47.0% | 48.0% | 50.2% | 40.2% | 50.9% | 50.1% | 30.2% |
| Pyroxene | 48.4% | 43.9% | 40.6% | 41.8% | 37.9% | 29.7% | 23.2% | 19.2% | 36.1% | 35.2% | 17.0% | 25.2% | 21.6% | 40.7% |
| Mesostasis | 4.6% | 19.8% | 11.4% | 26.3% | 21.4% | 26.3% | 37.5% | 32.6% | 13.7% | 14.1% | 38.2% | 21.8% | 25.4% | 28.1% |
| Iron Ore | 1.7% | 1.3% | 1.7% | 0.4% | 0.6% | 1.5% | 3.5% | 1.2% | 2.2% | 0.5% | 5.6% | 2.1% | 2.9% | 1.0% |

Modal analysis of dolerite specimens.

## TERTIARY SYSTEM

It is probable that Tertiary sediments occupy much of the Sandford Peninsula, although they are now overlain by a cover of Quaternary sands.

### Pipe Clay Lagoon Beds

On the southern shore of the entrance to Pipe Clay Lagoon, sandstones and clays are gently folded and interbedded with bands of limonite. The sandstone is friable and is light brown to chocolate brown in colour. Some cross-bedding is present. In section, the limonitic bands show a complexly crenulated structure. There is some resemblance to concretionary liesegang rings, but it seems more probable that intrastratal flowage and interal readjustmen along the clay layers has been responsible for the strucure. The crenulations become less pronounced close to the margin of the bed and the uniform thickness precludes large scale slumping.

The concretionary limonite probably originated as a lateritic coating, and this theory is supported by the presence of interbedded pure kaolin clay, a weathering product of potash feldspars. In the humid conditions necessary for lateritization, soda-lime feldspars and most silicates are completely hydrolysed. At the eastern end of the exposure the limonitic layers are almost vertical, but it is possible that the sandstones and clays retain a relatively shallow dip. No fossils have been found in these sediments, and the beds are overlain unconformably by flat-lying Quaternary sands.

A siliceous conglomerate with a chert matrix containing both angular and rounded pebbles of as much as 3 inches diameter occurs at 376084. The high degree of lithification suggests that the rocks are of Tertiary age and they appear to have been silicified, possibly by an overlying basalt flow which has since been eroded. Ironstone boulders found near the road to Seven Mile Beach, 322195, may also be of Tertiary age.

### Cape Contrariety Volcanic Centre

In the cliffs of a small bay immediately to the north of Cape Contrariety, 355935, a breccia-filled volcanic vent is exposed (Fig. 2). The vent is approximately ¼ mile in width with almost vertical contacts against dolerite on each side. The rocks are folded considerably and dips measured on the base of the basalt vary from 32° to 80° to the west. At the south end of the bay a plug 40 feet in diameter intrudes the breccia and is veined with calcite and zeolites.

The volcanic breccia is composed mainly of coarse angular fragments of gabbroic dolerite as much as 30 feet in diameter, set in a tuffaceous matrix. The unbedded and poorly-sorted breccia contains patches of fine scoriaceous basalt with a small amount of carbonate ad opaline cement. Close to the walls, the fragments consist entirely of pegmatitic dolerite, but in the centre of the neck as much as 10% of the fragments is composed of baked Grange Mudstone. A few large volcanic bombs occur in the cliff face.

Overlying the breccia are thirty-two feet of lithic tuff which is deep red to brown in colour, and contains tachylytic fragments and small vesicular flows of basalt. A few fragments of mudstone and dolerite of as much as two inches diameter are present, but these are well rounded. The tuff is poorly-bedded, very scoriaceous and veined by calcite and silica. Amygdules are of calcite, zeolites and opaline quartz.

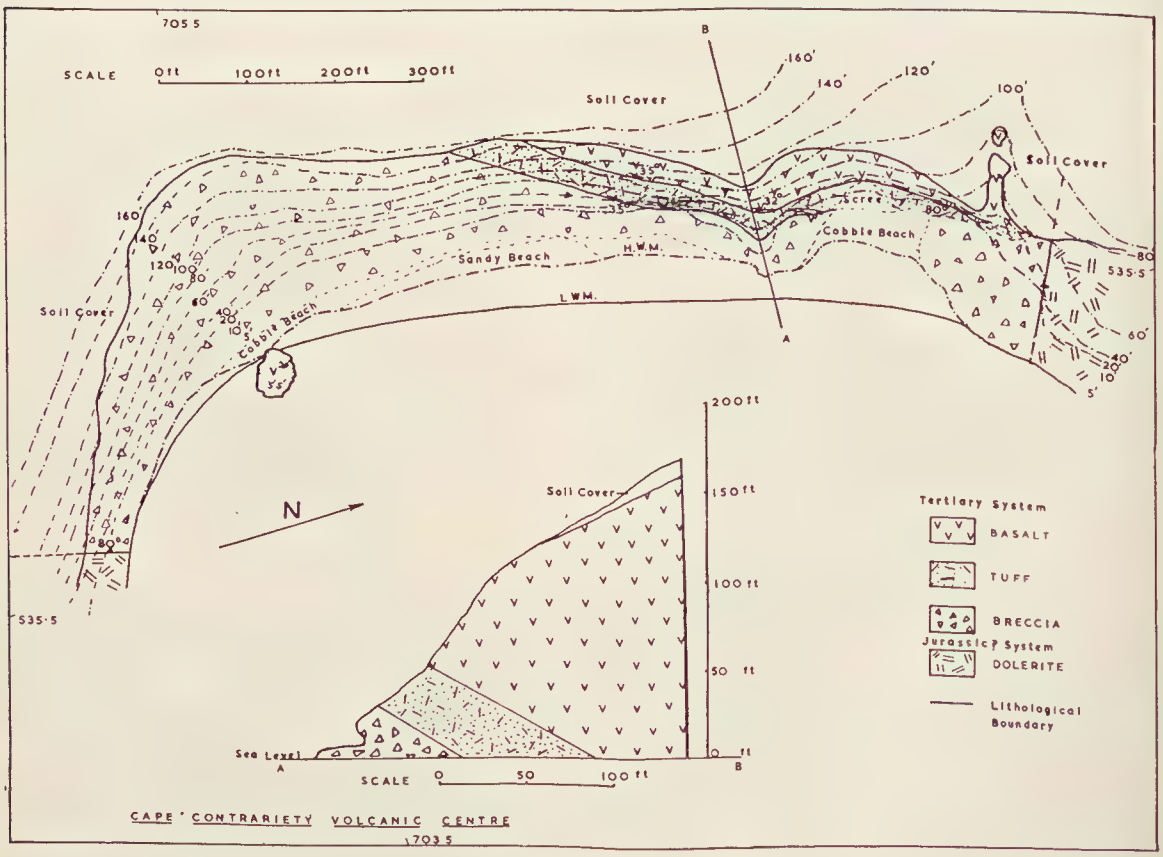


Figure 2.

The basalt fragments and small flows show well-formed olivine crystals. The top of the breccia is slightly baked by the overlying tuff and directly beneath the overlying basalt is a thin band of dark brown scoriaceous vitric tuff.

At least 100 feet of dark grey or reddish brown, fine-grained olivine basalt are exposed and as much as 150 feet may be present. Most of the basalt is massive, but the base is more vesicular and contains some sedimentary xenoliths. Basalt is exposed by minor landslips in the steep soil-covered slopes above the bay.

In hand specimen the rock is grey to brown in colour with yellow to red phenocrysts up to 8 mms. in diameter. The basalt is fine-grained, massive and vesicular to a small degree with amygdaloidal fillings of calcite, opaline quartz and zeolites. The olivine content of thin-sections (1032, 1033, 1039) ranges between 7 and 25% while the texture is markedly porphyritic with a very fine but almost entirely crystalline groundmass. Olivine is commonly altered to serpentine, which is found as a thin layer around the edges; a carbonate mineral and red iron oxides are other alteration products. Iron ore makes up about 10% of the rock and forms small rods, irregular fragments and euhedra in the groundmass.

Both pigeonite and augite occur as phenocrysts and the smaller microlites of pyroxene are of distinct relief and stained light green, they constitute approximately 30% of the rock. The phenocrysts of plagioclase are zoned from labradorite to andesine but the microlithic plagioclase shows very indefinite twinning and is probably albite or oligoclase. The large olivine phenocrysts have an intratelluric origin, as shown by their extensive late stage resorption and alteration.

The petrographic similarity of this basalt to the Rokeby basalt suggests that they are closely related.

The breccia-filled vent is probably due to an explosive phase of the Tertiary volcanism which has smashed the country rocks. Decrease of the gas pressure consequent upon magmatic withdrawal has allowed the angular blocks to fall back into the vent. At the same time as the explosive phase was in progress, some basalt entered the vent and formed a small amount of the matrix. The violently explosive phase was followed by the outpouring of interbedded lavas and tuffs and finally basalt. The folding is the result of subsidence into the vent rather than active control by the boundary faults and took place towards the end of the volcanic epoch.

**Rokeby Basalt and Volcanic Centre**

A dense, dark grey, fine-grained basalt outcrops strongly as benches at the top of Rokeby Hill, 276193. In the hand specimen (1030), the rock contains abundant olivine phenocrysts up to 2 mms. in diameter. Both massive and scoriaceous forms are present and the rocks sometimes have a ropy appearance.

On the east side of Rokeby Hill, a thickness of more than 200 feet of interbedded lavas and pyroclastics is exposed. The basalt is interbedded with volcanic breccia and subordinate tuff beds, the base of the basalt beds containing a few sedimentary xenoliths. The steep dip of these beds and the presence of a large number of interbedded flows and coarse pyroclastics suggest that a volcanic centre existed immediately to the east of this exposure and at approximately the position of the present town of Rokeby.

A structural break along the line of this valley is inferred from other evidence (see Structure). If the basalt on top of Droughty Hill has come from the same vent, it is likely that the top of the vent was at least 400 feet in height. The vent is now completely eroded and covered by Pleistocene and Recent alluvium.

In thin section (1027, 1030, 1031) the texture is porphyritic and the groundmass hyaloöphitic with a small proportion of intersertal mesostasis. The idiomorphic phenocrysts of olivine are almost entirely pseudomorphed in a crudely zonal manner by iddingsite. Olivine occurs as phenocrysts of up to 2 mms. in diameter and small granules constituting between 7 and 10% of the rock. Phenocrysts of augite (40%) and plagioclase laths (5%) of as much as 0.6 mm. in length are present. Iddingsite occurs as golden brown, slightly pleochroic lamellar pseudomorphs after olivine, the alteration following the cleavage cracks and the colour of the iddingsite becoming paler in distinct zones as the central core of unaltered olivine is approached.

Resorbed phenocrysts of altered olivine are surrounded by a layer of finely granular exsolved iron ore up to 0.06 mm. in diameter and it is likely that th outer zones of the olivine were originally richer in iron. The groundmass consists of microlithic laths of plagioclase (30%) with a mean length of 0.07 mm., short prismatic euhedral prisms of pyroxene (5%), small irregularly shaped granules of iron ore (approximately 5%) and small needles of apatite in a glassy isotropic material. The plagioclase laths are zoned and show a maximum extinction angle of 18° on albite twins, the extinction angle on the outside of the laths being as low as 8°. This suggests a composition of about $Ab_{65}$-$Ab_{75}$ (andesine-oligoclase).

Some degree of preferred orientation is shown by the pyroxenes, which exhibit a faint blue pleochroism and moderate second order interference colours. The glassy fine groundmass (5%) is clear, has a refractive index less than balsam, and contains turbid hexagonal outlines with very low relief, possibly of nepheline. Apatite is present as small needles which contain inclusions, but forms less than 1% of the rock.

The basalt (1122, 1123) on top of the hills above Droughty Point is petrologically very similar to the Rokeby basalt. The fine groundmass is glassy and only rarely can microphenocrysts of plagioclase and pyroxene be identified. Phenocrysts of completely iddingsitised olivine make up 10% of the rock.

A norm of the Rokeby basalt shows that the magma was undersaturated and is typical of the olivine basalt magma type. However, the high albite ratio (Wagner, 1956—89.9) suggests that the rock is differentiated. Although undersaturated, it

differs from the otherwise similar Blinking Billy Point basanite (Spry, 1955) in that it contains no normative nepheline.

Since 70-80% of the olivine in the Rokeby basalt has been altered to iddingsite, it is appreciably oxidised and the high state of oxidation is shown by the presence of haematite in the norm. The association of olivine phenocrysts in a groundmass of pyroxene, iron ore and a feldspar base is suggestive of a limburgite, a conclusion already drawn by Edwards (1950). A comparison may be made with the Hawaiian Alkaline Series of MacDonald (1949) and Wager (1956), in which basalts oligoclase are a middle stage differentiate.

TABLE II

| | *Rokeby basalt* | | | *Blinking Billy Pt. Basanite* | *Limburgite, Woodend Victoria* |
|---|---|---|---|---|---|
| $SiO_2$ | 46.64 | *Norm.* | | 45.59 | 45.10 |
| $Al_2O_3$ | 13.22 | or | 7.78 | 12.48 | 12.86 |
| $Fe_2O_3$ | 9.81 | ab | 34.58 | 9.93 | 5.66 |
| FeO | 4.16 | an | 3.50 | 2.84 | 7.10 |
| MgO | 7.01 | di wo | 6.73 | 4.71 | 8.56 |
| CaO | 7.33 | di en | 5.80 | 8.26 | 9.10 |
| $Na_2O$ | 4.11 | di fs | .. | 5.51 | 3.99 |
| $K_2O$ | 1.35 | hy en | 13.90 | 3.16 | 1.02 |
| $H_2O$ | 0.52 | hy fs | .. | 1.73 | 1.53 |
| $H_2O$ | 2.14 | ol fo | 5.74 | 1.64 | 1.10 |
| $CO_2$ | tr. | ol fa | .. | nil | tr. |
| $TiO_2$ | 2.50 | mt | 6.73 | 2.10 | 3.50 |
| $P_2O_5$ | 1.00 | hm | 5.12 | 1.65 | 1.00 |
| MnO | 0.19 | ilm | 4.71 | 0.16 | 0.08 |
| Cl | tr. | ap | 2.35 | 0.16 | tr. |
| $SO_3$ | nil | $H_2O$ | 2.66 | 0.09 | nil |
| ZrO | .. | | .. | .. | .. |
| | 99.98 | | 99.60 | 100.06 | 100.60 |

*Analyst:*—
W. St. C. Manson (from Edwards, 1950)
Aurousseau, 1926 (from Spry, 1955)
W. St. C. Manson (from Edwards, 1950)

The iron ratio (Wager, 1956—25.5) is low, suggesting that differentiation has not reached an advanced stage, although post-fractional oxidation will reduce the ratio to some extent. Since an alkaline residual liquid is characteristic of silica-deficient alkalic rocks, the mineralogical composition of the base depends upon the amount of silica present. Thus the apparent difference between the Rokeby basalt and the Blinking Billy Point basanite may be due to a small difference in the amount of silica present in the end products of crystallisation.

Small patches of scoriaceous basalt which are similar to the Rokeby basalt occur at 323115, 335115, 322105 and 333106. They are probably eroded remnants of a nearby volcanic centre.

**Pleistocene Series**

Much of the area is covered by Pleistocene gravels, sands and clays, some of which are terrestrial and shoreline deposits, while others are marine deposits and represent transgressive phases. Recent sands often obscure these deposits and it is difficult to define a line of demarkation. In some cases rounded pebbles of basalt occur in the gravels.

The Rokeby Rivulet has cut into a poorly-bedded series of impure clays and gravels and approximately one mile to the east, at the head of Ralphs Bay, are small cliffs of poorly-bedded gravels and sands. Although these gravels and sands are poorly consolidated, they stand in vertical cliffs of approximately 20 feet, and dip to the east at approximately 3°. The bounders and pebbles, derived mainly from Permian sediments, are angular, of low to moderate sphericity and show little evidence of fluviatile transport. The lower part of this exposure is better sorted and throughout the matrix is of silt to sand grade. Lenses of sandstone of limited lateral extent are common.

Similar gravels are exposed in a stream channel crossed by the Roches Beach Road, and along the Rifle Range Road where a bore passes through 82 feet of gravels before reaching solid rock. Cliff sections on the South Arm Peninsula show a similar thickness of gravels, sands and clays, which Nye (1924) has correlated with the gravels of the Sandford Peninsula.

At several points around the shoreline, consolidated cross-bedded sandstones occur. These are best exposed at the southern extremity of Droughty Point 264135 where the sandstone is slightly iron-stained, well-sorted and shows festoon current bedding and scouring of the upper parts of each bed. The bottom of each bed is commonly marked by a layer of pebbles or small broken shells. These deposits represent old storm beaches and have an origin similar to those forming the beaches of the present day. Similar deposit are found below the Recent sand dunes of Opossum and Half Moon Bays.

**Mary Ann Bay Sandstone.**

The Mary Ann Bay Sandstone is defined as that formation of friable, fossiliferous marine sandstone, approximately 40 feet thick and probably Pleistocene in age, which is overlain by Recent sands and rests unconformably on an irregular erosion surface of dolerite. The type exposure is in the cliffs of 246093, Mary Ann Bay.

This is a poorly consolidated friable sandstone, perched 60 feet above sea-level containing a few large pectinacean shells and a gastropod fauna very

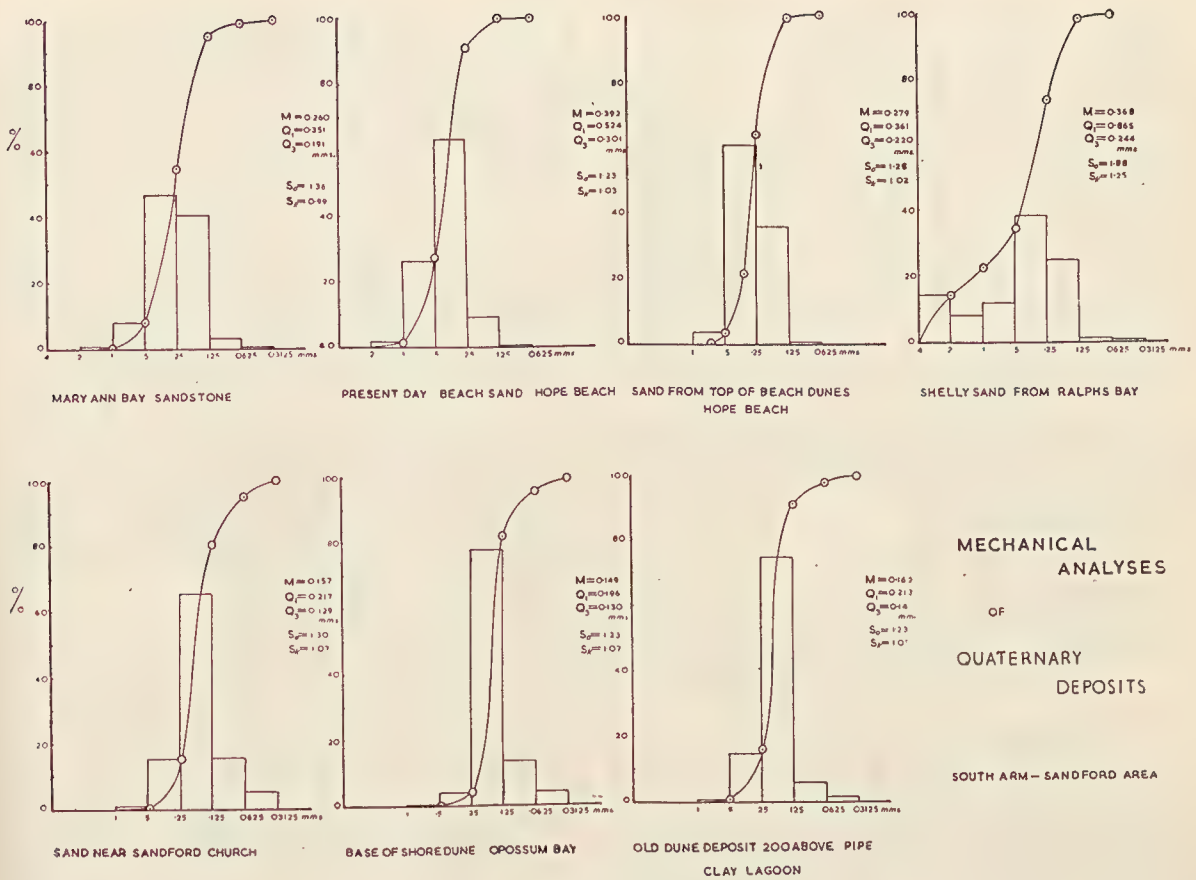
MARY ANN BAY SANDSTONE
PRESENT DAY BEACH SAND HOPE BEACH
SAND FROM TOP OF BEACH DUNES HOPE BEACH
SHELLY SAND FROM RALPHS BAY
SAND NEAR SANDFORD CHURCH
BASE OF SHORE DUNE OPOSSUM BAY
OLD DUNE DEPOSIT 200 ABOVE PIPE CLAY LAGOON
MECHANICAL ANALYSES OF QUATERNARY DEPOSITS
SOUTH ARM — SANDFORD AREA

Figure 3.

similar to that found on the present shoreline, although no determination of genera could be made. A mechanical analysis show that it is well-sorted (So = 1.36) and that there is a slight predominance of a coarse admixture. Most of the sand grains fall in the size range 0.5-0.125 mms. and they are subangular to rounded. The fossil fragments are broken but not abraded to any extent and form most of the coarse admixture.

**Recent Series.**

Almost the entire area with the exception of Hayes Hills, the hills to the east of Rokeby and Single Hill, is covered by Quaternary alluvium. A deep sandy soil covers all that area which lies below an altitude of approximately 100 feet. Much of the sand, being swept inland by the prevailing winds, is derived from old and present day shorelines. Most of the dunes are now stabilised by vegetation, with the exception of those near the exposed ocean beaches on the south coast. Marsh deposits have formed on the protected side of narrow necks and the saline swampy areas support a samphire vegetation.

Present day beach sands (1113) contain as much as 25% of subrounded shell fragments up to 4 mms. in size. Quartz particles range from 0.20 mm. to 1.5 mms. in grain-size, a few are subangular but the majority are subrounded. Almost all shell material falls in the 2 mms.-0.5 mms. size range. Sand from the top of the beach dunes (1114) contains quartz grains (90%), shell materials (7%), small rock fragments (3%) and some heavy minerals. This sample shows a decrease of 0.12 mms. in medium grain-size compared with that at the sea shore, is slightly better sorted and almost all the quartz grains are subrounded at least, showing the effect of some wind transport. The quartz particles are of moderate to high sphericity and the heavy minerals include zircon and ilmenite with a few small grains of rutile, magnetite, ? zoisite and sphene. No micas were found in this sample, another factor which indicates aeolian transport.

The inland dunes, which have suffered extensive wind transport, are characterised by excellent sorting (So = 1.2-1.3), a slight predominance of the finer admixture (Sk = 1.7) and the modal class is 0.25-0.125 mms. These deposits consist almost

entirely of quartz, subrounded to well-rounded in shape, and very few heavy minerals. Carbonaceous remains of roots are also present.

A distinct difference exists between the dune deposits on an exposed coast and those on the borders of sheltered bays and lagoons. Here the deposits are low shell ridges, the shells are often entire and the deposit is not as well sorted as a beach dune So = 1.88). A mechanical analysis of such a deposit at 309025 has a bimodal aspect (Fig. 3), with the secondary maximum consisting almost entirely of complete shells, including *Anapella cycladea, Cacozeliana cylindrica, Salinator fragilis, Mitrageuraleus australis?* and a small high spired gastropod. Heavy minerals (magnetite and zircon) account for less than 0.05% of this deposit. The subrounded to rounded quartz grains have a mean diameter of 0.25 mms.

A small clay drill lent by courtesy of the H.E.C., enabled the following section to be obtained at 350114 on the Cremorne Road near Pipe Clay Lagoon.

Top.

| | |
|---|---|
| 3″ | Black sandy soil |
| 24″ | Light brown sandy soil |
| 15½″ | Grey sand |
| 3″ | Alternation of grey and black sand ¼″ in thickness |
| 7″ | Grey sand with some clay matrix |
| 6″ | Sandy clay, slightly coarser at base |
| 57″ | Light grey-white pure clay—Tertiary. |

## STRUCTURAL GEOLOGY

### Faulting

The area has been extensively disturbed by parallel sets of normal faults which strike to the north or west of north. These faults, which are thought to be of Lower Tertiary age (Hills and Carey, 1949), consistently downthrow to the east. Since the strata dip to the west at approximately 10-15°, the strike faulting cause the repetition of one stratigraphic horizon, the Malbina Siltstone and Sandstone, which outcrops over most of the area.

The fault with the greatest displacement is probably that which forms the western boundary of a downfaulted area of Triassic sandstone at 322196, part of which was named by Lewis (1946) the Acton Fault. It is possible that the throw is as much as 1000 feet and that this fault continues to the south-east, as a chain of Lagoons follows the extension of the Acton Fault in this direction. There is no evidence to suggest that the fault on the eastern boundary of the downfaulted wedge (Single Hut Fault, Lewis, 1946) continues southward to Ralphs Bay, as a Permian sequence of Grange Mudstone to Ferntree Mudstone at 315180 is complete.

The next major fault to the west is that which follows approximately the line of the road to Clifton Beach (Rushy Lagoon Fault). The Malbina Siltstone and Sandstone along the western side of Pipe Clay Lagoon is downthrown to the extent of 400 feet against the Grange Mudstone on the western side of the road. This fault is intersected by the Clifton Fault (Lewis, 1946) which has upthrown the southern block by approximately 450 feet. If it is assumed that the dolerite at 347050 is dipping shallowly under the Grange Mudstone the Cape Contrariety Horst has risen a further 300 feet. The westward continuation of the Clifton Fault has a throw of approximately 200 feet. To the west of the Cape Contrariety Horst, Malbina Siltstone and Sandstone is downthrown and exposed at sea level.

A fault with a throw of aproximately 150 feet is required between Mt. Augustus and the low range of hills to the east, as the base of the Malbina Siltstone and Sandstone has risen by that amount. A fault with a throw of 250 feet must be inferred between Collins Springs and the hills to the north of Goat Bluff as dolerite is exposed at 323062 and the hills rise to 350 feet without exposing the Risdon Sandstone.

Mt. Mather and Mt. Augustus are separated by the Rifle Range Fault which has a throw of approximately 500 feet at the northern end. However, although a zone of crushed rock exists at 315116, the throw appears to decrease towards the south, as Malbina Siltstone and Sandstone outcrops on both sides of the fault.

At 302140, a pronounced drag dip is present on the shoreline. This fault, with the south side upthrown, does not have a throw of more than 50 feet, but dolerite is intruded along the fault line. Dolerite at White Rock Point is separated by a fault from the Malbina Siltstone and Sandstone of Opossum Bay. Lewis (1946 p. 157) considered this to be part of a Mount Louis-Single Hill fault line, but this conclusion is invalid because no evidence exists for the south-easterly extension of the Single Hill (Single Hut) Fault.

The Rokeby Fault (Lewis, 1946) is concealed beneath Tertiary volcanic rocks and Quaternary sediments and downthrows at least 300 feet to the east. North of Tranmere Point, the Malbina Siltstone and Sandstone becomes progressively steeper in attitude as the Tranmere Fault is approached. The dolerite forming Hayes Hills, south of the fault, has been upthrown.

The steep dip of the sediments exposed in a small quarry (295182) behind the Rokeby Church suggests that the contact with the dolerite has been faulted. This fault may be of Jurassic age, as the sediments are hardened near the contact and the dolerite is fine grained and deeply weathered. Malbina Siltstone and Sandstone form a downthrown wedge against the Rokeby Fault.

On the north-eastern tip of Betsey Island Triassic sandstones have been downthrown by two parallel faults, and the southernmost fault contact is marked by opal veins.

### The Form of the Dolerite Intrusions

As mentioned previously, the dolerite intrusions have a marked preference for one stratigraphic horizon, many of the contacts are sill-like but show a slightly transgressive relationship when examined in detail.

A steeply inclined intrustive contact is visible at 231197, the Malbina Siltstone and Sandstone is not highly baked, but the dolerite becomes fined-grained and well-jointed in the direction of the contact. This contact then swings to the north and across the Rokeby Road at 268196 where the intrusion becomes a thin dyke. The northern boundary of this intrusion is less well defined and the intrusion appears to have rafted up a block of mudstone, as the mudstone in the quarry at 267197 is closely jointed and strongly thermally metamorphosed.

The dolerite beneath Mt. Mather is a gently shelving sheet; on the shoreline the contact dips at a low angle under the Grange Mudstone. At May Point, 353162, the Grange Mudstone is underlain by dolerite which rises in a series of steps to a conformable contact at the top of the intrusion.

Clarence Hills are composed of dolerite which intrudes Permian sediments and dips steeply to the west. The contact is clearly exposed only at a height of 680 feet at 311187 where it is a normal intrusive contact. Nearer sea level the steep dip of the sediments suggests that they have been dragged the sense of the movement being eastern side upthrown. This is in the opposite direction to that which would be expected if the dolerite has caused the drag dip, and later fault movement along the line of the contact is a possible solution. The intrusive contact is cut by several Tertiary faults, the dolerite-sediment contact being clearly displaced at 310194.

The sill north of Cape Deslacs is concordant with the Grange Mudstone and dips gently to the southeast, while the dolerite forming Calverts Hill also appears to be concordant with the sediments to the north of a fault contact, as the well developed subhorizontal joints have the same dip as that of the sediments.

On the Cape Contrariety Horst an intrusive boundary has a steeper contact and dips under Grange Mudstone at 347051. The northern end of this contact (351055) is markedly transgressive and may be a Jurassic fault boundary. A thin tongue of dolerite intrudes the Grange Mudstone nearby.

### Joint Patterns.

A critical survey of joint patterns in the Malbina Siltstone and Sandstone was undertaken in an attempt to relate the well-developed jointing to the regional structure. The orientation of over 700 joints was determined in the field and plotted on a rose diagram (Fig. 4a.).

The most important are the near vertical joints striking at 250° (Set II), 295° (Set I) and 335° (Set III), and the same basic joint pattern is recognised over the entire area although the relative importance of individual sets varies from bed to bed. There is little evidence of horizontal displacement along the joints and joint planes cross pebbles without displacing them except for a tensional movement of approximately a millimetre in some joints of set III.

Differences in lithology are responsible for variations in the minor maxima but Set I are undeflected in passing through several beds. The joints of Set I are generally straight, have a maximum deviation of approximately 10° from the mean at any one locality and often occur in pairs about 9 inches apart. They have the characters of small shear joints. In exceptional cases this set may form a zig-zag pattern for a small distance.

A less well developed set of shear joints which are similar to Set I trend towards 250° (Set II) but show a maximum deviation of 15° from the mean. The prominent set of joints which follows the strike of the Tertiary faults (Set III) shows a considerable deviation from the mean and passes into feathery joints at the extremities. The surfaces of the joint planes are rough and these joints are parallel or sub-parallel to the strike of the strata.

Although the joints of Set I commonly truncate the others it has not been possible to determine a generalised sequence for the whole area. It is assumed that many of the joints are closely contemporaneous. In some cases Set I and Set II appear to be related, possibly as a conjugate pair of shear joints. At least some of the joints must be attributed to the intrusion of Jurassic dolerite, bu no distinction can be made.

Approximately 150 joints were measured during field mapping from the exposures of dolerite examined, the most important being vertical joints which trike at 230°, 10° and 320° and sub-horizontal joints. The near vertical joints tend to dip to the east at high angles.

The joints are irregular and of limited lateral extent. However, near intrusive contacts they are commonly parallel to the contact. Near such contacts the joints are often filled with silica, calcite and zeolites and occur as closely spaced plates.

There appears to be no correlation between Tertiary fault trends and the joints in the dolerite, but the joint pattern is rather similar to that produced for the Permian sediments, with one important addition, that of the joints striking at 230°.

### Geological History

The Grange Mudstone (Upper Artinskian) was deposited on a stable shelf and intercalations of limestone and dolomite occur frequently. Towards the top of the section clastic material becomes more frequent and calcarenites and granule conglomerates are interbedded with the mudstone. A slight erosional break was followed by the deposition of the basal member of the Malbina Siltstone and Sandstone as a small-scale turbidite deposit on a mildly unstable shelf. The adjacent land mass was rising either isostatically due to the melting of an ice cap, or due to epeirogenic movements. Icebergs dotted the surface of the sea and deposited their load as erratics. The depositional area became more stable as member "C" was deposited and towards the top of this formation conditions became more favourable for marine life.

The Risdon Sandstone has formerly been described as a near-shore deposit, but it is possible that it marks a period of instability rather than a drastic change in sea-level. The basin of accumulation appears to have become more shallow and during the deposition of the Ferntree Mudstone may have been virtually deltaic. The adjacent land surface at

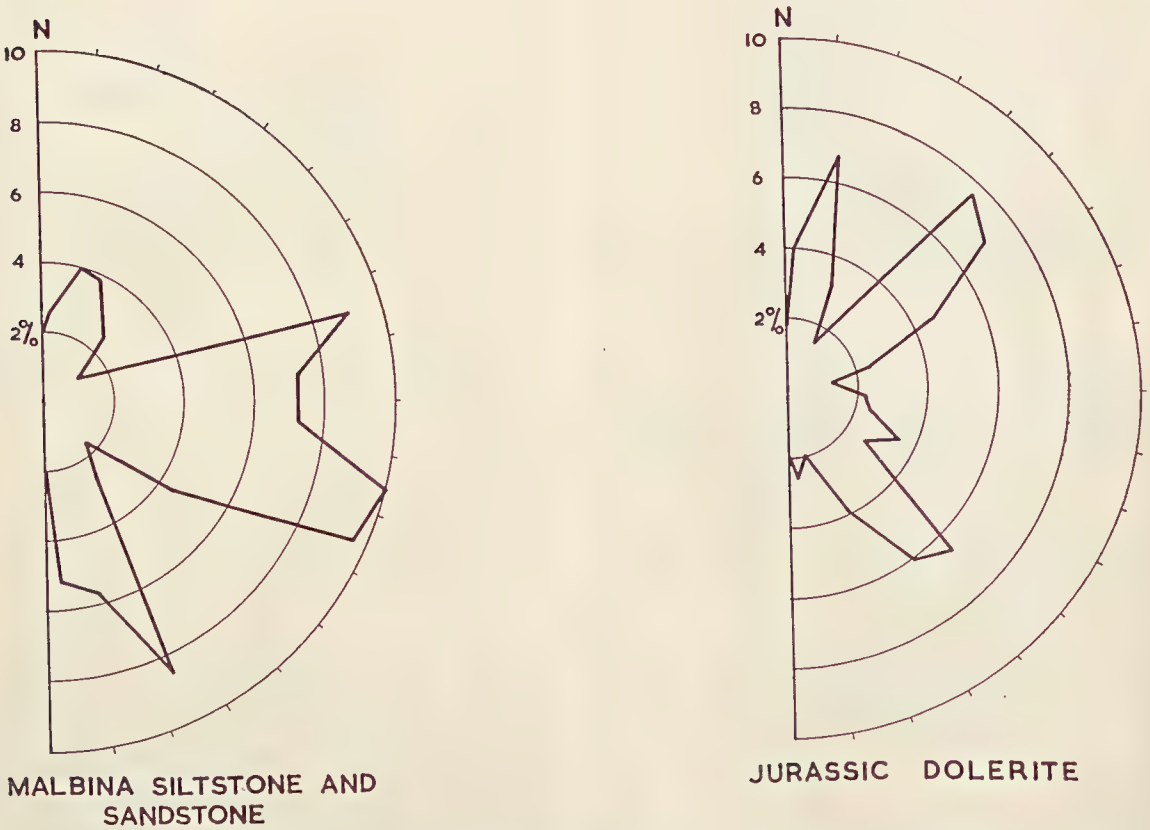


Figure 4.

this time was of low relief and the climate was becoming warmer as erratics are less frequent. Poorly-sorted sandstone bands, which occur at intervals show that periodically the area was slightly unstable.

The Ferntree Mudstone is separated from the basal Triassic grits by a possible disconformity. The quartz sandstones of the Triassic were probably deposited in lakes in a hot climates. The intrusion of Jurassic dolerite probably brought deposition to a close. The Permian and Triassic sediments were rafted in a sea of dolerite and the country rocks were thermally metamorphosed and silicified. The intrusion of the dolerite left the area with a considerable relief and it is likely that extensive erosion took place during the remainder of the Mesozoic, as it is probably that the topography of the early Tertiary landscape differed little from that of today. The Lower Tertiary conglomerates, sandstones, and clays were deposited at this point, probably in a series of lakes and lagoons.

The Lower Tertiary landscape was strongly disturbed by a series of northerly trending tensional faults. Explosive volcanic activity took place at centres which are situated near major Tertiary faults and the basalts flooded down the valleys left as a result of the Tertiary faulting. The basalts are deeply dissected. During the Pleistocene, extensive sand and gravel deposits accumulated over much of the area. Successive drops in sea-level have removed some of this material, but much of the area has been covered by Recent sand, which has been distributed by wind from both the present day and older shore dunes.

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## Locality Index

| | (Referred to State grid.) N. | E. |
|---|---|---|
| Blinking Billy Point | 716.7 | 521.3 |
| Campania | 747.8 | 527.3 |
| Cornelian Bay | 723.8 | 518.0 |
| Jarvis Creek (Claremont Square) | 736.3 | 504.0 |
| Lindisfarne | 725.0 | 521.5 |
| Mt. Rumney | 723.0 | 529.9 |
| Rathbone's Quarries, Mt. Nassau, (Claremont Square) | 736.8 | 506.3 |
| Richmond | 738.5 | 528.5 |
| Single Hill | 721.2 | 534.2 |

## APPENDIX

*Section in Cliffs at Cape Deslacs* (386006)

| Unit | ft. | ins. | | ft. | ins. | |
|---|---|---|---|---|---|---|
| Top. 5 | above | | | 91 | 6 | pebbly sandstone-graded—as described by Brill (1956). |
| 4 | 90 | 6 | — | 91 | 6 | coarse mudstone with few pebbles. |
| 3 | 88 | 7 | — | 90 | 6 | conglomerate—medium sand grade matrix. |
| | 80 | 3 | — | 87 | | inaccessible—this interval is covered in the section at the end. |
| 60 | 70 | 4 | — | 71 | 2 | shale—poorly fossiliferous. |
| 59 | 70 | 0 | — | 70 | 4 | pebbly limestone (? calcarenite). |
| 58 | 69 | 1 | — | 70 | 0 | dolomite—contains fenestellids and bryozoans. |
| 57 | 68 | 3 | — | 69 | 1 | mudstone with occasional fenestellids. |
| 56 | 67 | 11 | — | 68 | 3 | grey fiine granule conglomerate—graded and shows infillings of scoops in the unit below. |
| 55 | 67 | 8 | — | 67 | 11 | mudstone. |
| 64 | 67 | 5 | — | 67 | 8 | grey granule conglomerate—dolomitic matrix. |
| 63 | 66 | 10 | — | 67 | 5 | mudstone—cream with occasional fossils. |
| 62 | 66 | 7 | — | 66 | 10 | very fossiliferous fenestellid mudstone. |
| 51 | 66 | 6 | — | 66 | 7 | grey pebbly mudstone. |
| 50 | 65 | 10 | — | 66 | 6 | mudstone with fenestellids. |
| 49 | 65 | 0 | — | 65 | 10 | dolomite impure)—Fenestella, Stenopora-pebbly base. |
| 48 | 64 | 3 | — | 65 | 0 | fenestellid mudstone. |
| 47 | 64 | 0 | — | 66 | 3 | pebbly calcarenite—fossiliferous. |
| 46 | 61 | 1 | — | 64 | 0 | mudstone with calcareous fossils in bands at 62′ 0″ and 63′ 3″. |
| 45 | 61 | 0 | — | 61 | 0 | heavily weathered shale band. |
| 44 | 57 | 7 | — | 61 | 0 | impure limestone—grey in colour fossiliferous—fenestellids in muddy bands—has dolomite in thin layers—spiriferids, *Stenopora*. |
| 43 | 57 | 1 | — | 57 | 7 | pebbly calcarenite. |
| 42 | 55 | 3 | — | 57 | 2 | limy mudstone—abundant (60%) productids. |
| 41 | 54 | 11 | — | 55 | 3 | limestone, unfossiliferous. |
| 40 | 54 | 6 | — | 54 | 11 | limy mudstone. |
| 39 | 53 | 6 | — | 54 | 6 | fossiliferous impure limestone. |
| 38 | 53 | 1 | — | 53 | 6 | dark green mudstone. |
| 37 | 50 | 10 | — | 53 | 1 | fossiliferous limestone—few pebbles—massively bedded—spiriferid calcirudite in part. |
| 36 | 49 | 3 | — | 50 | 10 | shaly mudstone with fine-grained dolomitic intercalations. |
| 35 | 44 | 6 | — | 49 | 3 | fossiliferous (productid) limestone, with a few bands of dolomite and thin shaly bands. |
| 34 | 43 | 6 | — | 44 | 6 | fine sandstone. |
| 33 | 36 | 6 | — | 43 | 6 | very fossiliferous white or light blue limestone—massively bedded—contains productids, spiriferids, fenestellids and *Stenopora* spp.—only few pebbles of quartzite. |
| 32 | 36 | 5 | — | 36 | 6 | fine sandstone. |
| 31 | 35 | 6 | — | 36 | 5 | pebbly coarse sandstone. |
| 30 | 35 | 5 | — | 36 | 6 | sandstone. |
| 29 | 34 | 8 | — | 35 | 5 | dolomitic granule conglomerate—possibly graded. |
| 28 | 34 | 6 | — | 34 | 8 | fine sandstone band—? quartz veining along base. |
| 27 | 31 | 6 | — | 34 | 8 | slightly recrystallised dolomitic granule conglomerate pebbles up to 1″—very pebbly at base—large spiriferids 4″-5″ in width—no bedding visible. |
| 26 | 31 | 3 | — | 31 | 6 | finely laminated sandstone—? quartz veining along base. |
| 25 | 28 | 9 | — | 31 | 3 | dolomitic granule conglomerate—abundant poorly preserved fossils. |
| 24 | 28 | 0 | — | 28 | 9 | mudstone—dark olive grey in colour. |
| 23 | 27 | 0 | — | 28 | 0 | pebbly dolomite—*Stenopora* spp., brachiopods pebbles up to 2″. |
| 22. | 25 | 0 | — | 27 | 0 | limy mudstone, not well-bedded, Fe, Mn staining, apparently unfossiliferous. |
| 21 | 24 | 10 | — | 25 | 0 | pebbly band—calcareous matrix. |
| 20 | 22 | 11 | — | 24 | 10 | dolomite—a few pebbles up to 3″—mudstone intercalations 1″ in thickness—spiriferids. |
| 19 | 20 | 10 | — | 22 | 11 | mudstone—medium grey in colour—a few fenestellids. |
| 18 | 19 | 6 | — | 20 | 10 | very pebbly granule conglomerate—dolomitic matrix—pebbles up to 6″ (40%) very poorly sorted—thinly bedded mudstone at 20′ 4″. |
| 17 | 18 | 7 | — | 19 | 6 | slightly calcareous mudstone—½″ thick quartz vein at base. |
| 16 | 17 | 4 | — | 18 | 7 | pebbly mudstone—irregular base—pebbles up to 6″—most about ¼″—spiriferids at 17′ 7″. |

| Unit | ft. | ins. | | ft. | ins. | |
|---|---|---|---|---|---|---|
| | | — | | | | Base of Malbina Siltstone and Sandstone. |
| 75 | 79 | 6 | — | 80 | 3 | fossiliferous mudstone contains few well-rounded quartz pebbles up to 1½ inches—fenestellids. |
| 74 | 78 | 10 | — | 79 | 6 | pebbly calcarenite or fine granule conglomerate. |
| 73 | 78 | 4 | — | 78 | 10 | ? graded from coarse sandstone to mudstone. |
| 72 | 77 | 10 | — | 78 | 4 | ? graded from coarse sandstone to mudstone. |
| 71 | 77 | 2 | — | 77 | 10 | ? graded from coarse sandstone to mudstone—very pebbly—pebbles up to 2"—contains spiriferids. |
| 70 | 75 | 11 | — | 77 | 2 | dolomitic mudstone—shaly in part—few pebbles. |
| 69 | 75 | 7 | — | 75 | 11 | ? graded—irregular base—pebbly coarse mudstone. |
| 68 | 75 | 3 | — | 75 | 7 | ? graded pebbly mudstone. |
| 67 | 74 | 10 | — | 75 | 3 | limy mudstone. |
| 66 | 74 | 1 | — | 74 | 10 | pebbly granule conglomerate—few fossils possibly a dolomitic matrix. |
| 65 | 73 | 0 | — | 74 | 1 | mudstone with pebbly bands. |
| 64 | 72 | 9 | — | 73 | 0 | fossiliferous ? dolomite—grey in colour. |
| 63 | 72 | 2 | — | 72 | 9 | mudstone. |
| 62 | 72 | 1 | — | 72 | 2 | limy mudstone. |
| 61 | 71 | 2 | — | 72 | 11 | calcarenite—some quartz pebbles and fossils. |
| 15 | 17 | 1 | — | 17 | 4 | brown—dark grey medium-grained mudstone—poorly preserved calcite fossils with sheets of calcite. |
| 14 | 16 | 7 | — | 17 | 1 | ? graded bed—coarse sandstone at base—calcareous matrix—fossils (fenestellids) at top of unit. |
| 13 | 16 | 6½ | — | 16 | 7 | recrystallised sheets of calcite—1/16" thick. |
| 12 | 14 | 10 | — | 16 | 6½ | dolomite with *Stenopora*, fine mudstone bands at 15' 10" and 16' 5". |
| 11 | 14 | 4 | — | 14 | 10 | grey unfossiliferous mudstone—limestone. |
| 10 | 14 | 3 | — | 14 | 4 | lenses—limestone. |
| 9 | 14 | 0 | — | 14 | 3 | dark grey fine-grained mudstone—unfossiliferous. |
| 8 | 12 | 2 | — | 14 | 0 | dolomite white in colour. |
| 7 | 11 | 11 | — | 12 | 2 | heavily recrystallised green band (diopside). |
| 6 | 10 | 0 | — | 11 | 11 | recrystallised fossiliferous faint green dolomite mudstone—*Stenopora* in colonies—a few large spiriferids—replaced by prisms of diopside ? |
| 5 | 9 | 7 | — | 10 | 0 | light green very fossiliferous—productids—pebble of quartzite up to 4'. |
| 4 | 9 | 3 | — | 9 | 7 | grey mudstone—few fossils. |
| 3 | 8 | 6 | — | 9 | 3 | dolomite, white in colour, lenses of blue-grey limestone (2") a few fenestellids. |
| 2 | 8 | 0 | — | 8 | 6 | blue grey limestone—richly fossiliferous—a few small pebbles—*Stenopora*—90% of *Strophalosia* spp. are orientated convex upwards. |
| 1 | 0 | 0 | — | 8 | 0 | impure dolomite—with mudstone bands contains spiriferids, productids, few *Stenopora*, fenestellids rare—fossil broken and not well preserved—only fossils effervesce. |

Section begins approximately 5' above L.W.M.

*Supplementary section at Cape Deslacs.*

(To cover missing interval).

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | 90 | 0 | | | | sandstone—cream to grey in colour—medium grained. |
| 1 | 88 | 9 | — | 90 | 0 | coarse-grained sandstone, pebbly at base—grades up into unit above—at base this rock is a poorly-sorted conglomerate—matrix sand grade—a few finer patches—boulders of granite up to 1' diameter—angular pebbles of quartzite, schist, few of phyllite and mudstone—irregular base. This basal unit of the Malbina Siltstone and Sandstone. |

| Unit | ft. | ins. | | ft. | ins. | |
|---|---|---|---|---|---|---|
| 75 | 87 | 10 | — | 88 | 9 | coarse-grained mudstone—possibly |
| 71-74 | 87 | 10 | — | 88 | 9 | possibly limy—up to 10% pebbles. |
| 71-74 | 85 | 4 | — | 87 | 10 | coarse-grained sandstone—almost a grit—a few fossils. |
| | 79 | 5 | — | 85 | 4 | massively bedded pebbly mudstone—sandstones grey, weather yellow—a few calcareous fossils—bands of shale at 82' 3" and 84' 3" and small band of dolomite—possibly graded—fewer pebbles at top. |
| | 79 | 1 | — | 79 | 5 | graded bed—pebbly base—almost a grit—fossils (brachiopods) at base which is irregular. |
| | 79 | 1 | | | | pebbly mudstone—few pebbles. |

*Section Between West End of Hope Beach and Cape Direction* (269008-267004)

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 | 69 | | | | | cliffs of pebbly mudstone at least 70' in height and fine sandstone. |
| 13 | 55 | 8 | — | 69 | 0 | coarse-grained sandstone—unfossiliferous—matrix coarse sand—pebbles up to 2'—poorly sorted pebbles angular to subangular of quartzite and slate.—Pebbly layers at 55' 8", 57', 58' 1", 59' 6", 61' 0", 63' 0", 65' 6". |
| 12 | 55 | 1 | — | 55 | 8 | thinly bedded medium grained sandstone—few pebbles. |
| 11 | 53 | 10 | — | 55 | 1 | sandstone with few pebbles—may have gradational boundary with unit below. |
| 10 | 53 | 6 | — | 53 | 10 | coarse-grained sandstone—pebbles of quartzite up to 3". |
| 9 | 52 | 6 | — | 53 | 6 | massive pebbly sandstone—conglomerate at base matrix of sand grade—this unit is graded—pebbles of quartzite, slate and fenestellid mudstone. |
| 8 | 49 | 7 | — | 52 | 6 | fossiliferous mudstone—contains fenestellids and *Strophalosia* spp. |
| 7 | 48 | 10 | — | 49 | 7 | coarse sandstone—few fossils. |
| 6 | 44 | 7 | — | 48 | 10 | very fossiliferous mudstone—extremely rich in productids (*Strophalosia* or *Terrakea*). |
| 5 | 37 | 10 | — | 44 | 7 | unfossiliferous mudstone — few pebbles—massively bedded. |
| 4 | 35 | 6 | — | 37 | 10 | very fossiliferous mudstone—is hardened may have originally been calcareous rich in impressions of a spinose productid—possibly *Terrakea* ?—poor preservation precludes identification. |
| 3 | 34 | 4 | — | 35 | 6 | unfossiliferous coarse mudstone. |
| 2 | 25 | 6 | — | 34 | 4 | pebbly fine sandstone—bedding approximately 18" thick—pebbly layer at 32' 6". |
| 1 | 0 | 0 | — | 25 | 6 | pebbly mudstone and fine sandstone—bedding 1' 6" to 2' 6" thick—pebbles appear to be more frequent at base of beds. |

*Section Along North End of Ralphs Bay near Ralphs Bay Canal* 315174 *to* 308173.

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | 60 | 7 | — | 71 | 0 | massive pebbly sandstone—coarse bands at intervals of 3" to 1". |
| 10 | 60 | 5 | — | 60 | 7 | granule conglomerate. |
| 9 | 60 | 0 | — | 60 | 5 | coarse mudstone, unfossiliferous. |
| 8 | 59 | 7 | — | 60 | 0 | pebbly granule conglomerate. |
| 7 | 59 | 4 | — | 59 | 7 | coarse mudstone. |
| 6 | 59 | 0 | — | 59 | 4 | pebbly granule conglomerate—matrix about ¼" diameter. |
| 5 | 57 | 1 | — | 59 | 0 | slightly pebbly fine sandstone—mudstone intercalations. |
| 4 | 56 | 6 | — | 57 | 1 | pebbly sandstone. |
| 3 | 54 | 6 | — | 56 | 6 | conglomerate—poorly sorted matrix of very coarse sand—mean size of boulders 4"-5" and they make up 30% of the unit—one boulder is of granite 16" diameter also quartzite—subangular, Permian mudstone—angular to subangular and quartz mica schist—rounded and 2-3" in in diameter. |

| Unit | ft. ins. | | ft. ins. | | |
|---|---|---|---|---|---|
| 2 | 53 | 9 — | 54 | 6 | graded bed—coarse sand to mudstone —pebbles up to 3" diameter. |
| 1 | 53 | 0 — | 53 | 9 | very pebbly sandstone—pebbles up to 6" of quartzite and granite—finer towards top—probably graded—very irregular base—possibly some current markings on the base of this unit although no current directions could be measured.—this unit is probably the base of the Malbina Siltstone and Sandstone. |

Grange Mudstone.

| | | | | | |
|---|---|---|---|---|---|
| 42 | 52 | 0 — | 53 | 0 | medium grained mudstone —fissile |
| 41 | 51 | 0 — | 52 | 0 | coarse mudstone with one pebble 4" diameter at base; few fenestellids. |
| 40 | 50 | 6 — | 51 | 0 | pebbly granule conglomerate. |
| 39 | 50 | 0 — | 50 | 6 | Graded bed, granule conglomerate to mudstone. |
| 38 | 48 | 6 — | 50 | 1 | fine-grained sandstone—fenestellids and spiriferids. |
| 37 | 45 | 5 — | 48 | 6 | pebbly calcarenite—with sandy bands pebbles up to 1" at 46' 0", 46' 8", 47' 2". |
| 36 | 44 | 4 — | 45 | 5 | fine-grained sandstone — coarse-grained mudstone—few fenestellids pebbly at base—possibly graded. |
| 35 | 43 | 2 — | 44 | 4 | fine to medium-grained sandstone—pebbly base, graded. |
| 34 | 42 | 10 — | 32 | 2 | mudstone fissile. |
| 33 | 42 | 6 — | 42 | 10 | coarse mudstone. |
| 32 | 41 | 0 — | 42 | 6 | fissile mudstone. |
| 31 | 40 | 0 — | 41 | 0 | fine granule conglomerate. |
| 30 | 34 | 5 — | 40 | 0 | fissile mudstone, fossiliferous—contains bryozoans, productids and occasional molluscs. |
| 29 | 33 | 6 — | 34 | 5 | *Strophalosia jukesi—Fenestella* limestone. |
| 28 | 30 | 6 — | 33 | 6 | limy mudstone—extremely fossiliferous—*Strophalosia* spp., fenestellids, stenoporids molluscs and a few gastropods. |
| 27 | 27 | 5 — | 30 | 6 | sparsely pebbly fine-grained mudstone some bands calcareous. |
| 26 | 26 | 9 — | 27 | 5 | coarse grained mudstone—fossiliferous. |
| 25 | 24 | 10 — | 25 | 9 | mudstone with recrystallised calcite fossil shells—a few pebbles up to 1". |
| 24 | 23 | 11 — | 24 | 10 | mudstone with rolled fragments of brachiopods. |
| 23 | 23 | 0 — | 23 | 11 | typical Grange fenestellid mudstone. |
| 22 | 22 | 0 — | 23 | 0 | fossiliferous coarse sandstone—pebbly at top productids and bryozoans. |
| 21 | 20 | 11 — | 22 | 0 | limy fenestellid mudstone—a few small grains of sand size. |
| 20 | 20 | 0 — | 20 | 11 | this bed contains an intact bryozoal mat (*Stenopora crinita*) 8" in length but the remaining fragments appear to have been rolled. |
| 19 | 19 | 2 — | 20 | 0 | mudstone very rich in broken fragments of bryozoa—almost a coquina. |
| 18 | 18 | 10 — | 19 | 2 | coarse sand grade—contains small gastropod. |
| 17 | 17 | 11 — | 18 | 10 | coarse mudstone, unfossiliferous. |
| 16 | 17 | 0 — | 17 | 11 | slightly pebbly mudstone—calcareous fossils bryozoans, fenestellids. |
| 15 | 14 | 11 — | 17 | 0 | pebbly fine granule conglomerate—pebbles up to 1" of quartzite, granite( slate, green schist—this unit appears to be graded and the base is irregular. |
| 14 | 13 | 9 — | 14 | 11 | coarse pebbly mudstone—a few pebbles up to 4". |
| 13 | 13 | 2 — | 13 | 9 | slightly limy mudstone with spiriferids. |
| 12 | 12 | 7 — | 13 | 2 | granule conglomerate. |
| 11 | 12 | 6 — | 12 | 7 | fissile mudstone. |
| 10 | 10 | 11 — | 12 | 6 | blocky coarse mudstone—fossils in layers—productids and pectens—few pebbles up to 2". |

one graded unit

| Unit | ft. ins. | | ft. ins. | | |
|---|---|---|---|---|---|
| 9 | 7 | 9 — | 10 | 11 | mudstone, fairly fossiliferous—less than 3% pebbles (up to 2")—contains brachiopods, fenestellids and stenoporids. |
| 8 | 7 | 7 — | 7 | 9 | white mudstone. |
| 7 | 6 | 9 — | 7 | 7 | limy mudstone—spiriferids, fenestellids and bryozoans towards top of bed. |
| 6 | 4 | 7 — | 6 | 8 | rather fissile mudstone. |
| 5 | 4 | 6 — | 4 | 7 | pebbly layer. |
| 4 | 3 | 6 — | 4 | 6 | graded unit, pebbly coarse mudstones at base (almost a granule conglomerate), mudstone, at top contains fenestellids. |
| 3 | 2 | 2 — | 3 | 6 | ? graded unit—very coarse mudstone at base which contains a few brachiopods—fenestellids are restricted to upper part of the bed. |
| 2 | 0 | 9 — | 2 | 2 | fossiliferous mudstone—rather fissile —a few pebbles. |
| 1 | 0 | 0 — | 0 | 9 | very pebbly coarse mudstone-pebbles up to 6"—poorly sorted—10% of the pebbles are over 1" in size. Section covered by pebble beach. |

*Section Westwards Along Shore from Jetty, South Arm.*

Malbina Siltstone and Sandstone.

| | | | | | |
|---|---|---|---|---|---|
| above | 45 | 0 | | | coarse mudstone—few pebbles—bedded 18" to 2'—fissile in places. |
| 20 | 39 | 6 — | 45 | 0 | mudstone with a few pebbles, beds 13" to 18" thick. |
| 19 | 38 | 6 — | 39 | 6 | typical cream mudstone. |
| 18 | 38 | 0 — | 38 | 6 | coarse pebbly mudstone. |
| 17 | 36 | 0 — | 38 | 0 | pebbly mudstone—few pebbles up to ½". |
| 16 | 34 | 6 — | 36 | 0 | blocky mudstone—rather fissile at base-pebbles up to 2". |
| 15 | 33 | 6 — | 34 | 6 | fine sandstone—many small pebbles. |
| 14 | 27 | 6 — | 33 | 6 | pebbly coarse mudstone—not well-bedded—poorly exposed. |
| 13 | 25 | 8 — | 27 | 6 | pebbly coarse mudstone—possibly has gradational boundary with unit beneath. |
| 12 | 24 | 0 — | 25 | 8 | pebbly fine sandstone—pebbles in rows, many large pebbles up to 1', most 3"-4"—massively bedded. |
| 11 | 21 | 0 — | 24 | 0 | pebbly mudstone—a few pebbles up to 6" most 1"-2"—elongated markings up to 4". |
| 10 | 20 | 0 — | 21 | 0 | mudstone—fewer pebbles. |
| 9 | 19 | 7 — | 20 | 0 | coarse mudstone approximately 3% pebbles up to 1"—irregular wave-like bottom contact, wavelength 2'. |
| 8 | 13 | 8 — | 19 | 7 | very pebbly mudstone—pebbly bands at 19' 0", 17' 0", 13' 9" very pebbly band (quartzite, sandstone, mudstone, and slate up to 4") at 14' 5". |
| 7 | 12 | 3 — | 13 | 8 | sparsely pebbly mudstone. |
| 6 | 9 | 10 — | 12 | 3 | moderately pebbly mudstone, up to 3% pebbles over 1"—pebbles range from angular to well rounded—very pebbly base—quartzite pebbles up to 1'. |
| 5 | 7 | 6 — | 9 | 10 | coarse mudstone—fissile towards top. |
| 4 | 5 | 7 — | 7 | 6 | slightly pebbly mudstone. |
| 3 | | | | | |
| 2 | 0 | 0 — | 5 | 7 | medium-grained mudstone — few pebbles in patches bedding from 1' 3" and 2" thick. |
| 1 | | | | | |

*Section Along Shoreline Beneath Mount Mather,* 313158 *to* 307155

Malbina Siltstone and Sandstone

| | | | | | |
|---|---|---|---|---|---|
| 48 | 120 | | above | 120 | coarse pebbly mudstone, bedding 8"-1' 6" thick. |
| 47 | 90 | 0 — | 120 | 0 | pebbly sandstone—bedding 1'-2' thick. |
| 46 | 89 | 0 — | 90 | 0 | coarse mudstone. |
| 45 | 87 | 0 — | 89 | 0 | pebbly sandstone. |
| 44 | 85 | 0 — | 87 | 0 | sandstone. |

| Unit | ft. | ins. | | ft. | ins. | |
|---|---|---|---|---|---|---|
| 43 | 80 | 0 | — | 85 | 0 | massively bedded sandstone—a few fossils (spiriferids)—few large pebbles up to 4", 1 or 2 of granite. |
| 42 | 76 | 0 | — | 80 | 0 | sandstone—few pebbles. |
| 41 | 75 | 6 | — | 76 | 0 | mudstone. |
| 40 | 74 | 6 | — | 75 | 6 | sandstone. |
| 39 | 74 | 0 | — | 74 | 6 | unfossiliferous mudstone. |
| 38 | 71 | 9 | — | 74 | 0 | slightly pebbly sandstone. |
| 37 | 71 | 0 | — | 71 | 9 | mudstone. |
| 36 | 69 | 3 | — | 71 | 0 | sandstone. |
| 35 | 67 | 0 | — | 69 | 0 | pebbly sandstone—massively bedded. |
| 33 | 64 | 8 | — | 67 | 0 | sandstone—a few pebbles. |
| 32 | 64 | 5 | — | 64 | 8 | unfossiliferous mudstone. |
| 31 | 64 | 3 | — | 64 | 5 | pebbly conglomerate. |
| 30 | 63 | 10 | — | 54 | 3 | fossiliferous coarse mudstone. |
| 29 | 63 | 7 | — | 63 | 10 | granule conglomerate. |
| 28 | 62 | 8 | — | 63 | 7 | fossiliferous mudstone—spiriferids, stenoporids and fenestellids. |
| 27 | 62 | 4 | — | 62 | 8 | pebbly conglomerate. |
| 26 | 61 | 6 | — | 62 | 4 | sandstone—few pebbles—well-sorted. |
| 25 | 60 | 0 | — | 61 | 6 | unfossiliferous mudstone. |
| 24 | 59 | 0 | — | 60 | 0 | sparsely pebbly sandstone. |
| 23 | 58 | 1 | — | 59 | 0 | fenestellid mudstone. |
| 22 | 53 | 0 | — | 58 | 1 | sparsely pebbly and fossiliferous mudstone few *Stenopora* and *Fenestella* at top. |
| 21 | 50 | 2 | — | 53 | 0 | massively bedded resistant very pebbly granule conglomerate, matrix coarse sand, pebbles up to 6" few fossils. |
| 20 | 49 | 0 | — | 50 | 2 | fine mudstone. |
| 19 | 47 | 2 | — | 49 | 0 | coarse pebbly mudstone—pebbly base. |
| 18 | 46 | 7 | — | 47 | 2 | mudstone. |
| 17 | 46 | 7 | — | 46 | 7 | pebbly granule conglomerate. |
| 16 | 41 | 6 | — | 45 | 7 | coarse fossiliferous mudstone—bedding about 1' thick—spiriferids in layers, also fenestellids, pebbly at base. |
| 15 | 36 | 7 | — | 41 | 6 | coarse pebbly fossiliferous mudstone—contains an alate spiriferid and *Fenestella* in finer bands. |
| 14 | 36 | 0 | — | 36 | 7 | fine fenestellid mudstone (also *Stenopora* spp). |
| 13 | 35 | 1 | — | 36 | 0 | pebbly fine granule conglomerate—angular pebbles. |
| 12 | 31 | 0 | — | 35 | 1 | fossiliferous mudstone—fossils of $CaCO_3$, fenestellids, stenoporids, spiriferids, *Ingelarella*—*Ingelarella* always associated with the coarser bands. |
| 11 | 27 | 10 | — | 31 | 0 | pebbly fine granule conglomerate with sandstone matrix—fossils in layers—specimen of *Ingelarella* in sandstone at top of bed—possibly graded. |
| 10 | 27 | 0 | — | 27 | 10 | mudstone, occasional pebbles. |
| 9 | 26 | 11 | — | 27 | 0 | granule conglomerate. |
| 8 | 25 | 6 | — | 26 | 11 | fossiliferous sandstone—contains pectens, bryozoans, spiriferids and an ingelarellid which is more bulbous than the more common species—preservation very poor. |
| 7 | 23 | 6 | — | 25 | 6 | pebbly mudstone—poorly exposed. |
| 6 | 22 | 6 | — | 23 | 6 | covered by sand and soil—no structural break. |
| 5 | 19 | 6 | — | 22 | 6 | pebbly granule conglomerate—irregular bottom contact—matrix of sand grade—pebbles up to 4"—abundant moulds of spiriferids which are aligned—graded. |
| 4 | 15 | 5 | — | 19 | 6 | coarse-fine pebbly mudstone—few fossils—infrequent pebbles up to 2"—one or two brachiopods at 16' 7". |
| 3 | 13 | 0 | — | 15 | 5 | pebbly coarse sandstone—few large pebbles of quartzite and phyllite up to 1'—many spiriferids—poor preservation. |
| 2 | 12 | 9 | — | 13 | 6 | fine sandstone—granule conglomerate at base. |
| 1 | 10 | 9 | — | 12 | 9 | basal bed of Malbina Siltstone and Sandstone—matrix is sand grade—pebbles low sphericity, subangular, quartzite, slate and mudstone up to 1'—a few fenestellids at top—poorly preserved moulds of spiriferids aligned parallel to bedding—base is a calcirudite—many pebbles of underlying Grange Mudstone. |

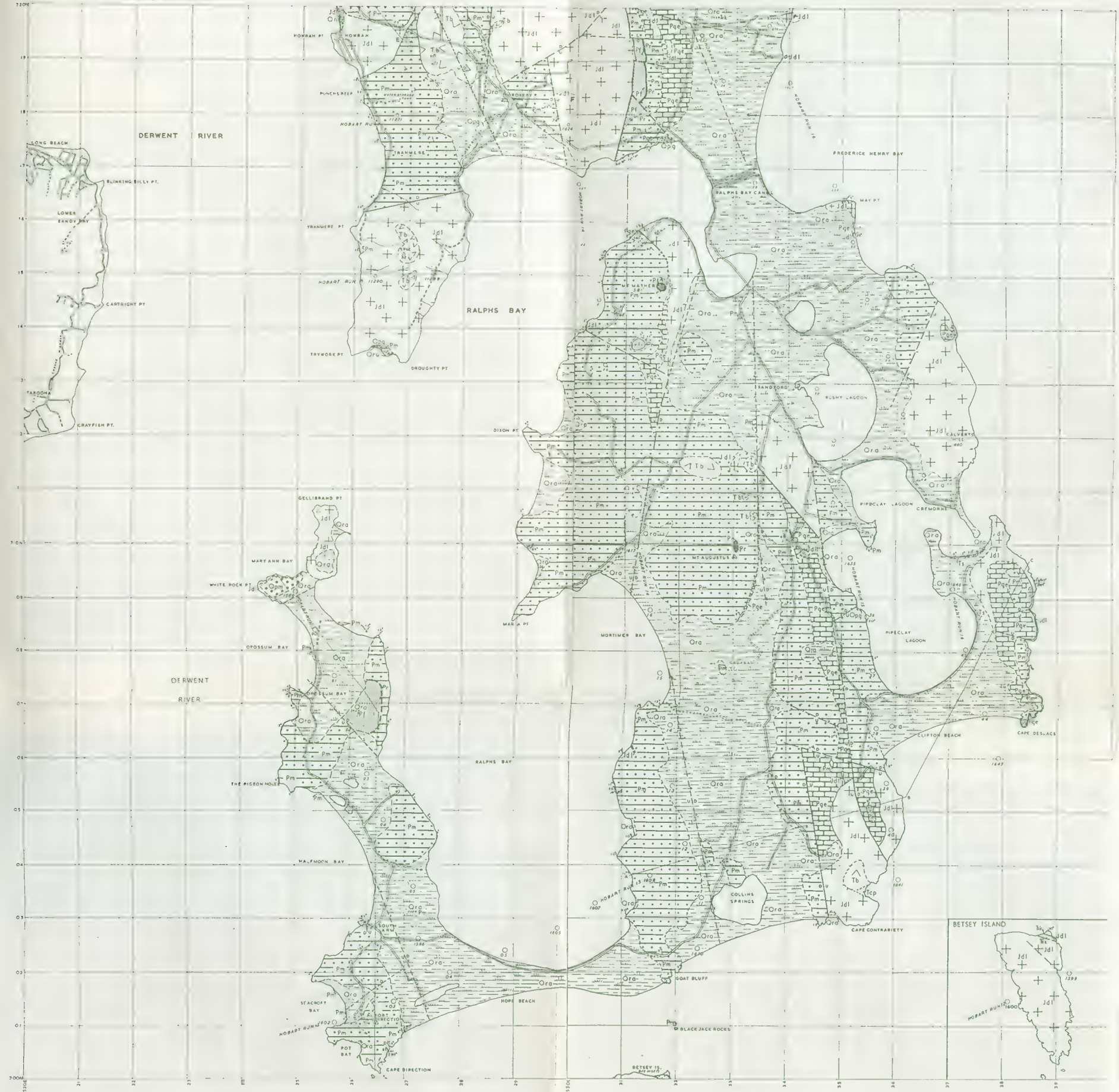
Grange Mudstone.

| | | | | | | |
|---|---|---|---|---|---|---|
| 15 | 10 | 7 | — | 10 | 9 | calcirudite—only of limited lateral extent. |
| 14 | 10 | 6 | — | 20 | 7 | mudstone. |
| 13 | 10 | 5 | — | 20 | 6 | calcirudite—granule conglomerate—lens. |
| | 6 | 10 | — | 10 | 5 | partly covered by boulders, limy mudstone—many pebbles—calcarenite in part. |
| 12 | 6 | 5 | — | 6 | 10 | richly fossiliferous mudstone—fenestellids. |
| 11 | 5 | 11 | — | 6 | 5 | calcirudite, similar to that at Cape Deslacs. |
| 10 | 5 | 6 | — | 5 | 11 | fissile mudstone. |
| 9 | 4 | 6 | — | 5 | 6 | sparsely fossiliferous mudstone. |
| 8 | 4 | 1 | — | 4 | 6 | coarse mudstone—fossiliferous. |
| 7 | 4 | 0 | — | 4 | 1 | fossil coquina and calcarenite. |
| 6 | 3 | 3 | — | 4 | 0 | fenestellid mudstone—a few pebbles—appears to be graded—almost a calcarenite at base. |
| 5 | 2 | 10 | — | 3 | 3 | fossiliferous mudstone—faintly silicified contains alate spiriferid. |
| 4 | 2 | 6 | — | 2 | 10 | calcirudite—calcarenite, rolled fossil fragments. |
| 3 | 1 | 10 | — | 2 | 6 | mudstone, few pebbles or fossils. |
| 2 | 1 | 0 | — | 1 | 10 | richly fossiliferous unit, almost a coquina, contains *Fenestella* spp., *Polypora*, *Ingelarella*, spiriferids, productids, pectens and a small gastropod—preservation poor—a few quartzite boulders up to four inches in diameter. |
| 1 | 0 | 0 | — | 1 | 0 | thinly bedded limy mudstone—weathered green to yellow in colour at contact with dolerite. Gently shelving intrusion, rather irregular contact but contact effects not pronounced. |
| | | | — | ? | ? | Dolerite |

# GEOLOGY OF SOUTH ARM

GEOLOGY OF TASMANIA

ONE INCH SERIES — UNIVERSITY OF TASMANIA, GEOLOGY DEPARTMENT



## LEGEND

- FAULT CONCEALED
- FAULT-DOWNTHROWN SIDE INDICATED
- FAULT-POSITION APPROXIMATE
- FAULT INFERRED
- FORMATION BOUNDARY
- FORMATION BOUNDARY-POSITION APPROXIMATE

Dolerite Boundaries

- CONCORDANT SILL
- DISCORDANT INTRUSIVE BOUNDARY
- VERTICAL JOINTS
- DIP AND STRIKE OF JOINTS
- DIP AND STRIKE OF STRATA
- ROAD
- VEHICULAR TRACK

Quaternary System

RECENT SERIES

- ALLUVIUM

PLEISTOCENE SERIES

- SANDS AND GRAVELS
- MARY ANN BAY SANDSTONE

Tertiary System

- PIPECLAY LAGOON SANDS AND CLAYS

Triassic System

- KNOCKLOFTY FORMATION

Permian System

- FERNTREE FORMATION
- RISDON SANDSTONE
- MALBINA SILTSTONE AND SANDSTONE
- GRANGE MUDSTONE

IGNEOUS ROCKS

Tertiary System

- BASALT
- CAPE CONTRARIETY PYROCLASTICS

Jurassic System

- DOLERITE

Compilation from Aerial Photographs Trigonometrical Station Control in part by courtesy of the Department of Lands and Surveys Hobart.
Origin of co-ordinates 400,000yds. West and 1,800,000yds. South of True Origin of Zone 7 of the International Grid.

KEY MAP SHOWING MAGNETIC DECLINATIONS 1957
SECULAR VARIATION 7 MINS P A

MAPPED AND COMPILED BY D.C.GREEN, 1959

— SCALE —

0 1 2 MILES

0 1 2 3 4 5 10,000 FEET

MERCURY

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# TASMANIAN BEACH RIDGE SYSTEMS IN RELATION TO SEA LEVEL CHANGE

By

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(With 1 plate and 8 text figures.)

## ABSTRACT

Both sand and pebble beach systems in Tasmania show an overall decrease in height seaward which may be correlated with a fall of sea-level occurring while they were being formed. This fall from the postglacial Milford shoreline was of the order of 2 or 3 ft. in south-eastern Tasmania, but about 5 or 6 ft. elsewhere.

## INTRODUCTION

At several points along the northern and eastern shores of Tasmania (Fig. 1) are systems of numerous, low, sub-parallel, frontal dunes to which the name of sand beach ridges is usually given. Their general appearance is shown by Plate 1. The ridges may vary in amplitude from a few inches to about 20 feet and represent stages in a gradual progradation of the shore. The factors affecting their development have been discussed previously (Davies, 1957).

The ridge systems always lie between the present shore and the older, slightly higher, shoreline of the Milford sea level, which, although it has not yet been precisely dated, seems certainly to represent the limit of postglacial marine transgression (Davies, 1959). The ridges may thus have formed at the Milford level, at the present level, or during the fall in sea level from the one to the other. On this assumption their initiation must have been at some time in the last 6,000 years and such a maximum age is supported by the evidence of profile development in the sands, which shows that shell content decreases and humus content increases gradually to landward.

Material coarser than sand is rare on Tasmanian beaches and the only extensive pebble beaches are those on the north coast between and around the mouths of the Forth and Mersey rivers. Their localisation here is probably associated with the function of these two rivers as important outlets of glacial meltwater in the late Pleistocene. Immediately east of the Forth at Lillicos Beach is a well marked complex of pebble ridges representing a series of storm beaches on a prograding shore. As with the sand ridge systems, the Milford shoreline runs to landward and it would seem that the pebble ridges are more or less contemporary with the sand ridges described above.

## SAND RIDGE SYSTEMS.

Each ridge in a sand ridge system comprises a wave built berm of sand or shell on top of which wind driven sand has accumulated in the form of a low dune. The relative amount of dune sand present varies within individual systems and also between systems. The sand ridges of the Bass Strait coast, which are open to strong sand-shifting winds from the north-west, contain notably more aeolian sand than do those of the east coast. The amplitude of the ridges at Black River, Port Sorell and Greens Beach (Figs. 2, 3, 4) is consequently greater than those at Swansea, Rheban, Seven Mile Beach and Roches Beach (Figs. 5, 6 and Davies, 1958). One may note too that the Bass Strait ridge systems are more irregular in height, since the amount of wind blown sand in a ridge varies much more than the

Fig. 1.—Location of sand ridge systems.

amount of wave deposited material. The height of the beach berm is almost entirely controlled by the maximum height of the constructing waves and this factor will not show great and erratic variation from ridge to ridge. On the other hand the thickness of the wind blown material will depend mainly on the length of time that the ridge operates as an accumulation form, which in turn will depend on the length of time which it takes for a new ridge to establish itself to seaward. This factor is potentially much more variable.

It could be expected therefore that the height of the hidden beach berm nucleus would reflect wave height at the time of construction and, provided other factors such as tidal range and offshore wave refraction patterns remained constant, any variation in the height of the berm from ridge to ridge would be an approximate measure of sea level change. However, this record is submerged beneath the wind blown material capping the berms, which, because it varies with a different factor, tends to mask trends which might otherwise be discernible. Even so, it has been suggested that variation in height of the ridges can be used as evidence of sea level change and Gill and Banks (1956) pointed to the apparent significance of the Black River ridges in this connection. Ideally an exact assessment of trends would necessitate the identification and levelling of the top of the wave built section in each ridge, but the writer has suggested (Davies, 1958) that the calculation of a line of best fit for surface ridge and swale heights would give an approximation to sea level trends over the entire period of ridge formation. The calculation of lines of best fit by the method of least squares for ridges and swales at Seven Mile Beach and Roches Beach showed a gradual overall slope seaward of about 2 to 3 feet.

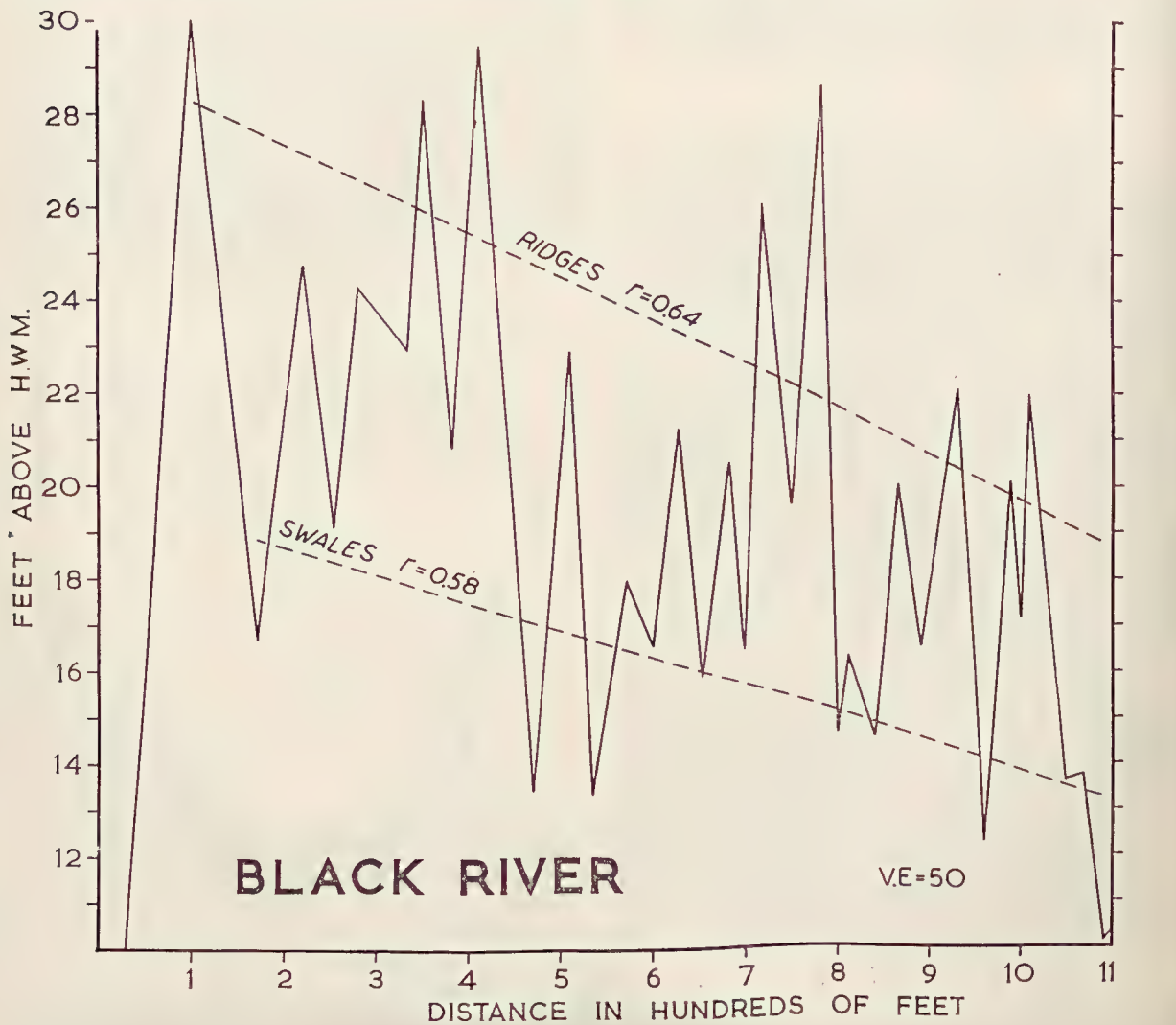


FIG. 2.—Profile of sand ridge system at the Black River, with lines of best fit and product moment correlation coefficients (r.).

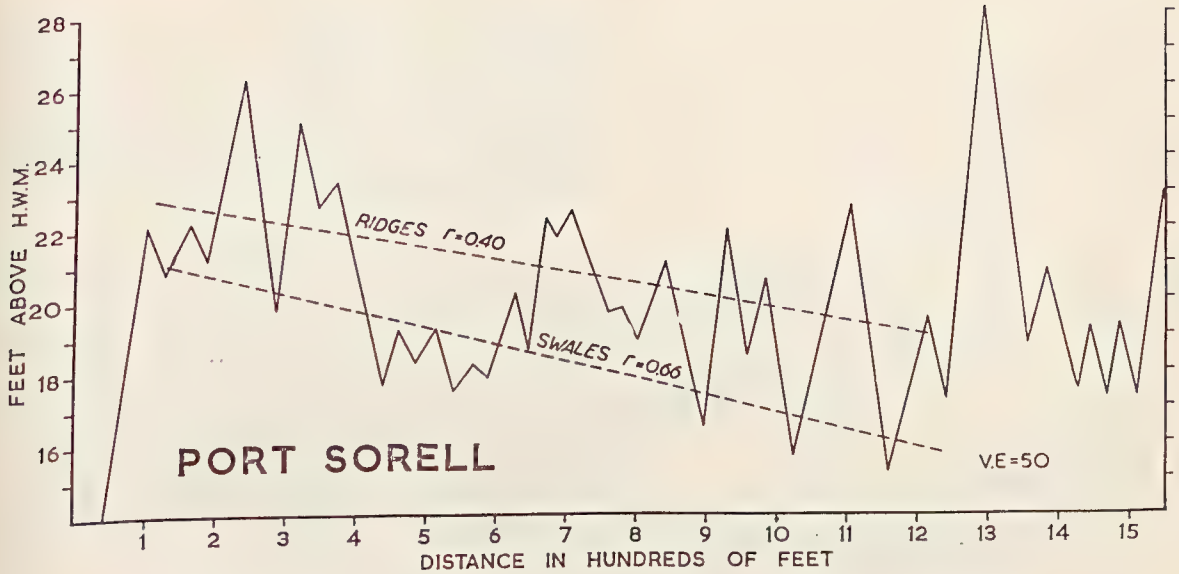


FIG. 3.—Profile of sand ridge system at Port Sorell.

Survey and analysis of other sand ridge systems has since shown that such simple statistical analysis of surface form provides an almost consistent story of correlation between ridge building and sea level fall. The additional systems analysed were those of Black River, Port Sorell and Greens Beach on the Bass Strait coast and of Swansea and Rheban on the east coast.

**Black River** (Fig. 2).—The ridge system at the mouth of the Black River has been described and figured by Gill and Banks (1956). There is a ridge amplitude of up to about 17 feet and this results from the comparatively large amount of dune sand contained in the ridges. This in turn is reflected in the irregularity of ridge height. As a result, although the lines of best fit suggest an overall seaward slope of the system of about 9 feet for ridges and 5 feet for swales, the fit is not a particularly good one and the product moment correlation coefficient (r) in each case, while satisfactory, is not very high.

**Port Sorell** (Fig. 3).—The wide Rubicon ria at Port Sorell is partly closed by a large baymouth bar, progradation of which has given rise to an extensive sand ridge system (Plate 1). The ridges show great variation in amplitude and the surveyed profile poses some difficulties. The greatest of these perhaps is due to the presence of the highest (28 ft. above H.W.M.) ridge close to the seaward edge of the system. In calculating the lines of best fit only the ridges and swales behind this ridge have been used, on the assumption that the exceptionally large ridge marks a point of sudden and marked slowing in the ridge building process with the consequent accumulation of a much larger mass of dune sand. Such a procedure is open to criticism on grounds of subjectivity and since the correlation coefficient for ridges here is a low one (0.40), it would seem preferable anyway to treat the evidence of the Port Sorell ridges with some reserve.

**Greens Beach** (Fig. 4). Greens Beach is near Kelso, immediately west of the Tamar mouth, and here there is a well defined system of over twenty ridges with amplitudes of 1-6 ft. They contain a smaller amount of dune sand than do the ridges at Black River and Port Sorell so that the correlation coefficient for the line of best fit is very satisfactory (0.81). The lines of best fit suggest an overall drop in height seaward of 10 ft. for ridges and 8 ft. for swales.

**Swansea** (Fig. 5). The ridge system at Swansea occurs on the large spit of Nine Mile Beach which almost closes the head of Oyster Bay. The system is a large one, being about three-fifths of a mile wide, but the ridges are the lowest and least distinct of any surveyed. The amount of wind blown sand which they contain is very small and excavation suggested that it does not cap the underlying beach berms to a depth of more than 2 feet.

The result is that correlation coefficients are very high (0.88 for ridges and 0.92 for swales) and the system shows a very clear and steady slope seaward of about 5-6 ft.

**Rheban** (Fig. 6). The Rheban system, while genetically similar to the others, is different in two main ways. In the first place, two cross profiles of this system showed an overall tilt to landward instead of to seaward as in all other instances. One of these profiles is analysed in Fig. 6 where a tilt of 2-3 ft. is suggested by lines of best fit. The second difference, which is undoubtedly connected with the first, lies in the much more complicated history of this system. The ridges comprise a bar in Carrickfergus Bay at the mouth of the Sandspit River

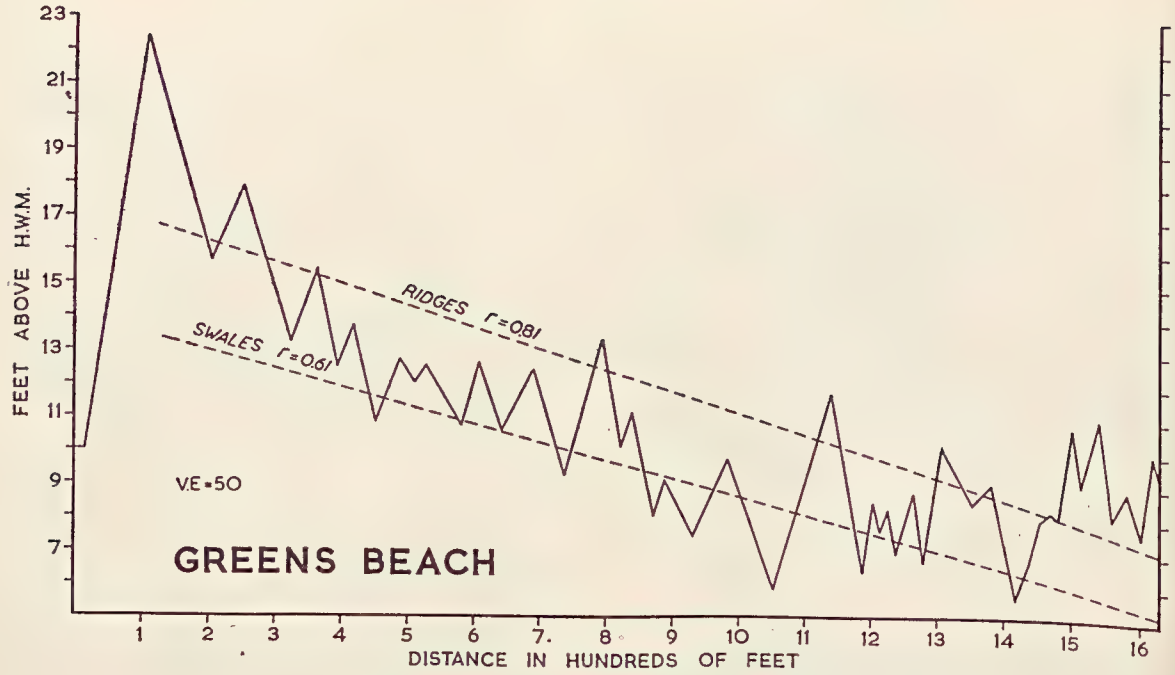


FIG. 4.—Profile of sand ridge system at Greens Beach.

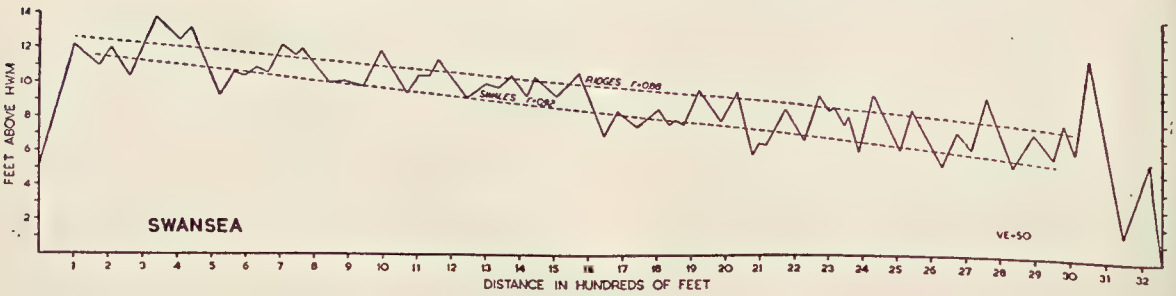


FIG. 5.—Profile of sand ridge system at Swansea. Dunes at the extreme right have been omitted from calculations because they are actively accumulating at the present sea level.

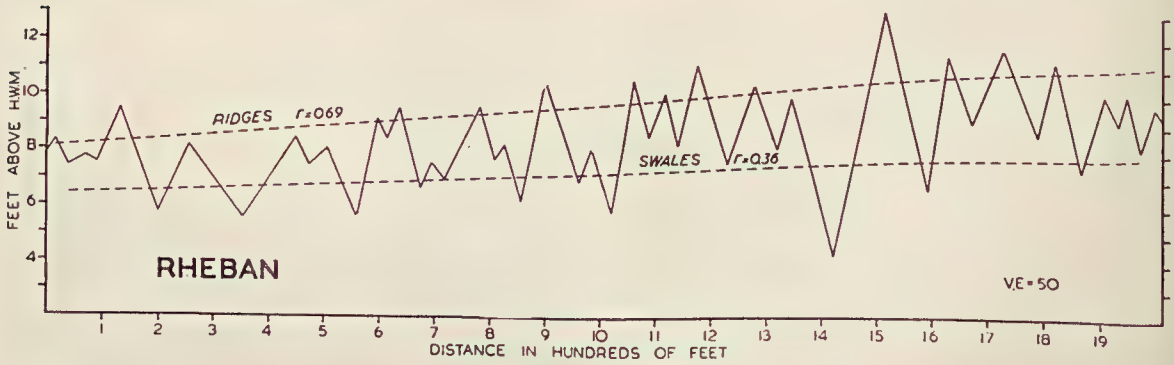


FIG. 6.—Profile of sand ridge system at Rheban. As in all sand ridge profiles the sea is towards the right.

and their development has been controlled by two sets of waves—one approaching from north of Maria Island and one from the south. The interaction of these two sets of waves, varying in character with time, has given rise to considerable unconformity in plan which is not found in other ridge systems. A detailed study of the evolution of this system seems necessary before the significance of the apparent tilt can be properly appreciated.

## PEBBLE RIDGE SYSTEMS.

Unlike the sand ridges, pebble ridge systems contain no wind-blown component and owe their total height directly to the height of the constructing waves. One would therefore expect their surface form to be a much better reflection of the height of the sea at the time of their construction.

**Lillicos Beach.**—A cross profile of the Lillicos Beach pebble ridges about half a mile east of the mouth of the Forth (Fig. 7), shows that they decrease generally in height seaward by a total of about 5 feet. Other profiles are consistent with this, but nearer the river mouth the drop in height is rather less.

## DISCUSSION

The evidence derived from analysis of the sand ridge systems is summarised in the Table below, where the figures for Seven Mile Beach and Roches Beach have been added to those of the systems figured here.

| System | | Tilt in ft. | r |
|---|---|---|---|
| Black River | Ridges | 9 | 0.64 |
| | Swales | 5 | 0.58 |
| Port Sorell | Ridges | 4 | 0.40 |
| | Swales | 5 | 0.66 |
| Greens Beach | Ridges | 10 | 0.81 |
| | Swales | 8 | 0.61 |
| Swansea | Ridges | 5 | 0.88 |
| | Swales | 6 | 0.92 |
| Rheban | Ridges | 3 | 0.69 |
| | Swales | 2 | 0.36 |
| Seven Mile Beach | Ridges | 4 | 0.70 |
| | Swales | 2 | 0.70 |
| Roches Beach | Ridges | 3 | 0.93 |
| | Swales | 2 | 0.74 |

All except the Rheban complex show an overall tilt to seaward of both ridge and swale heights and this tilt also appears in the pebble ridges of Lillicos

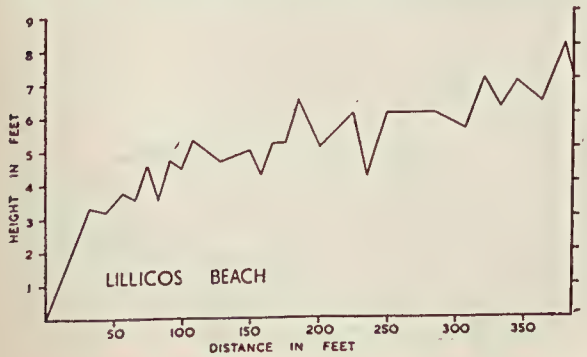


FIG. 7.—Profile of pebble ridge system at Lillicos Beach

FIG. 8.—Height of the Milford Shoreline above high water mark.

Beach. There is consequently, and for the reasons suggested ealier, a very strong presumption that sea level was falling while the ridges were being formed.

The extent of this sea level fall may be gauged approximately from the table and would appear to have been about 2-4 ft. in south-eastern Tasmania, but about 5-10 feet elsewhere. Such figures agree extremely well with figures obtained by other methods for the difference in height between the Milford sea level and the present. The figures for the height of the Milford shoreline plotted in Fig. 8 have been derived from instrumental levelling of the foot of Milford cliffs and the head of Milford beaches and salt marshes and comparison with comparable features controlled by present sea level. These figures also show a smaller fall in the south-east (2-3 ft.) compared with a slightly higher fall elsewhere (5-6 ft.). A similar, but somewhat greater, difference is noticeable in heights obtained from Llanherne shoreline, formed at an older higher level. In south-eastern Tasmania this lies at about 12-15 ft. above present high water mark, but elsewhere figures of 18-22 ft. have been recorded for what appears on all the evidence to be the same shoreline.

The exact significance of this apparent tilt of the Milford and Llanherne shorelines cannot yet be assessed. It may reflect an actual downward movement of the land in the south-east, but it could also conceivably be brought about by other factors such as local changes in tidal range. Since differences in height between the Llanherne levels are somewhat greater than those between Milford levels it might be deduced that, whatever the process may be, it has been going on since before the time of the Milford sea.

In summary then, there are three lines of evidence which, taken together, strongly suggest that the ridge systems were built during the fall from the

Milford sea level. First, the ridges are all seaward of the Milford shoreline and were consequently built since it was initiated; second, they display a drop in height of the same order as that recorded for other features of the Milford shore; and third, they show the same difference in this drop as between the south-eastern coast and the other coasts of Tasmania.

## ACKNOWLEDGEMENTS

The writer would like to acknowledge gratefully the help of Dr. A. J. Hagger, Mr. R. J. Solomon, Mr. J. A. Peterson and third year students of the Geography Department, University of Tasmania in surveying some of the ridge systems discussed here He owes a particular debt to Mr. E. A. Nash who assisted in surveying all the systems on the Bass Strait coast.

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Plate 1.—Sand ridge system at Port Sorell. The sub-parallel ridges are crossed obliquely by parabolic or "blow-out" dunes initiated by burning and grazing of the ridges in the latter half of the nineteenth century. Agricultural land behind the ridges mostly comprises raised Milford salt marsh and the Milford shoreline runs approximately along the inner edge of the cleared land.

# NOTES ON THE EXTERNALS OF THE POTOROO, POTOROUS TRIDACTYLUS (KERR).

By

Eric R. Guiler

(With 1 plate and 9 figures.)

## ABSTRACT

This paper is the sixth describing features of the biology of the potoroo. The externals and the body proportions of the species are described and the ratio of pes-shank is compared with that of two other Tasmanian macropods. The ratio in each species is closely similar. The length of the hand in relation to the length of forelimb of *Potorous tridactylus* is slightly greater than in either *Wallabia rufogrisea* or *Thylogale billardieri*. The population can be divided by weight into the adult and subadult groups from the histograms given.

The Potoroo, *Potorous tridactylus* (Kerr) is common in many parts of Tasmania, but it is still a comparatively little known marsupial. The species was once plentiful on the mainland of Australia but has since become very rare, Marlow (1958) recording that the last two specimens of this species known to have been caught in New South Wales were taken in 1913 and 1958 respectivly. *Potorous tridactylus* once inhabited coastal South Australia but Jones (1924) noted that the species was to be considered extinct in that State. Beyond casting doubts as to whether the species ever existed in Central Australia, Finlayson (1958) had little to say about *Potorous*.

This species was selected some years ago as one suitable for investigation and three papers have already appeared on the general biology of the species (Guiler, 1957, 1958 and 1960).

*Potorous trdactylus* inhabits the coastal scrub region in Australia and it is distributed in Tasmania from sea level to 3,500 feet, living in regions of thick scrub or forest, usually with some water, but is absent from plains and open forest.

Jones (1924) briefly described the externals of *Potorous* but it is not clear from his description whether he was using Australian or Tasmanian material. He was using a small number of specimens and gave measurements of two specimens of which one was Tasmanian in origin. It is certain that he did not use South Australian animals.

There are few detailed descriptions of the externals of any Tasmanian marsupials and in view of the rarity of this species on the mainland of Australia it is appropriate that such a description be on record. A total of 122 animals has been used in the preparation of this paper.

*Potorous tridactylus* is generally assigned to the subfamily Potoroinae of the family Macropodidae, the other two subfamilies being the Hypsiprymnodontinae and the Macropodinae.

## COLOUR

Potoroos are usually brown in colour ranging from a lightish shade to a dark chestnut. The most frequent variety is a rich dark brown. The colour of each individual hair is dark in the proximal portion but with a light fawn coloured distal region. This gives a flecked appearance to the animal when it is viewed closely.

The suborbital regions are a lighter shade than the general colour of the body and the hairs near the rhinarium are dark. Some individuals have a very thin dark line running up the snout from the rhinarium to the ears. There is a lighter coloured area situated on the face above the vibrissae and below the darker dorsal surface of the snout.

The edges of the ears are darker in colour than the remainder of general body surface. The ears are hairy on the outer surface but are only sparsely covered by hair on the inner surface.

The central surface is a grey to light fawn colour and this grades into the general body colour on the flanks. The pouch entrance in the female is stained yellow, but this may not be observed when the sphincter is tightly closed.

The proximal quarter of the tail is of the general body colour but this grades into a dark brown or, in some individuals, black. The end of the tail frequently has white hairs usually associated with a non-pigmented tip. This is a very variable feature and will be discussed more fully below.

Albinos and melanics are not known in *Potorous tridactylus* though dark coloured animals are common in the more humid parts of Tasmania.

Pouch young are very dark brown in colour and juvenile individuals are always darker than the adults. The animal gradually becomes a lighter shade during its early post pouch life and animals of up to two years of age can be identified by their colour. Old animals of greater age than 4 years have a large number of grey brown hairs, especially the males, and some six year old animals have been caught which are a grizzled grey colour.

The feet are hairy on the upper surface and are the same colour as the general body surface.

## TAIL

The tail exhibits considerable variation in the colouring of the tip, the end of which usually bears white hairs and these are usually underlain proximally by darkly pigmented skin. The distal portion

is often non-pigmented and appears as a pinkish region. In only one animal in 89 examined on Mt. Nelson, near Hobart, did the non-pigmented area reach as far as the proximal end of the white hairs. I have not found an animal in which the non-pigmented region is longer than the white hair covered portion. One animal had a ring of dark pigment in the non-pigment portion.

Some animals do not have either a white tip or non-pigmented region to the tail. The presence or absence of a white tip has little apparent significance. Some populations may have a high percentage of all black tails whereas others have no black tailed individuals. The examination of 147 animals showed that there was no sexual difference in the possession of this character and that the proportion of individuals possessing the feature varied from time to time in the one population.

The length of the white tip plotted against the length of the non-pigmented area (Fig. 1) shows that there is, in general, a relationship between the length of the tip and the length of the non-pigmented area i.e. those animals with long white tips tend to have a long part without pigment, but there is no sexual difference in the proportion. There are some strong deviations from the normal relationship, particularly in females having a white tip about 45 mm. in length. The largest tips were possessed by females and the smallest by males but this may be fortuituous due to the composition of the sample.

The length of the white tip and unpigmented region shows no relationship to the length of the tail (Fig. 2). This is true of both sexes.

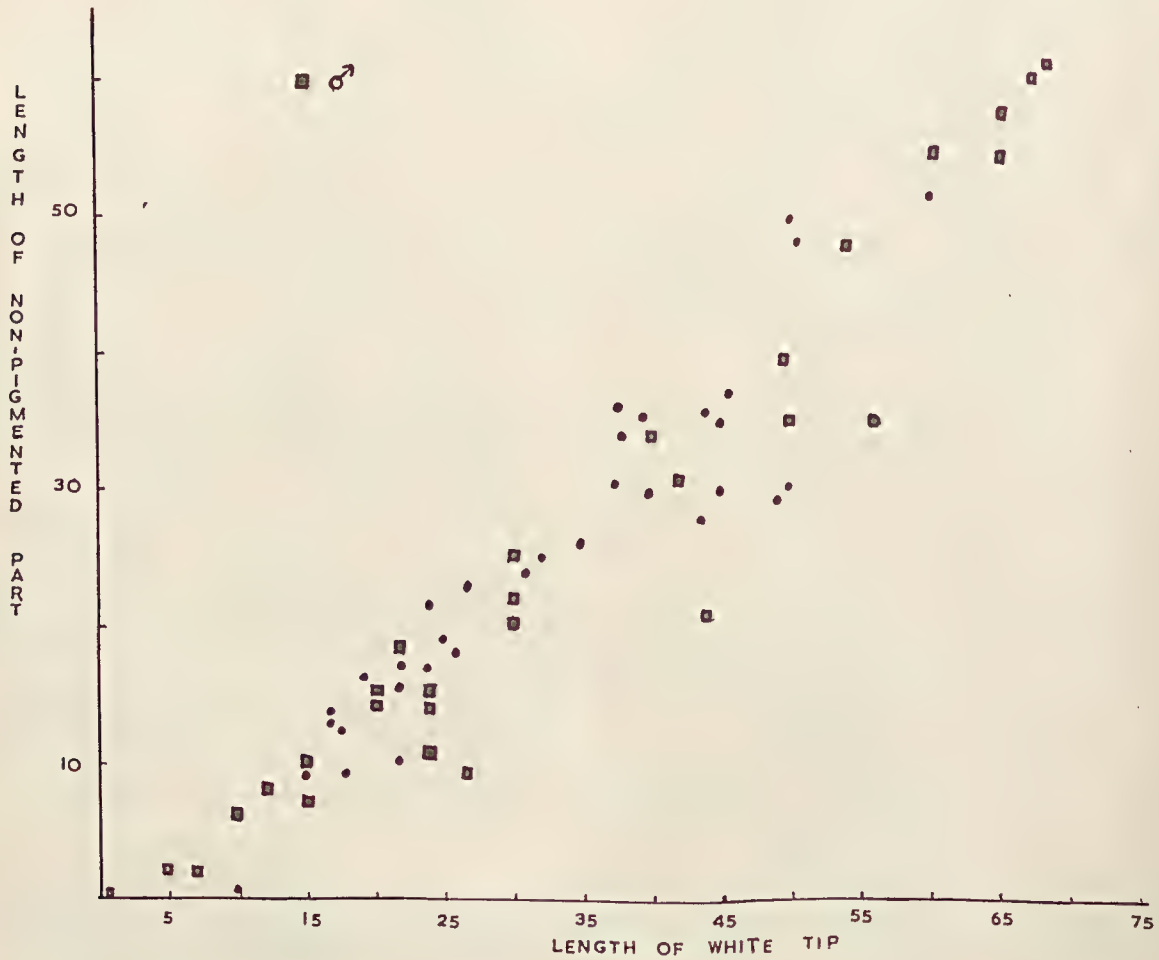


Fig 1.—The length of the white tip on the tail of male and female *Potorous tridactylus* in relation to the length of the non-pigmented area of the tail (in cms.).

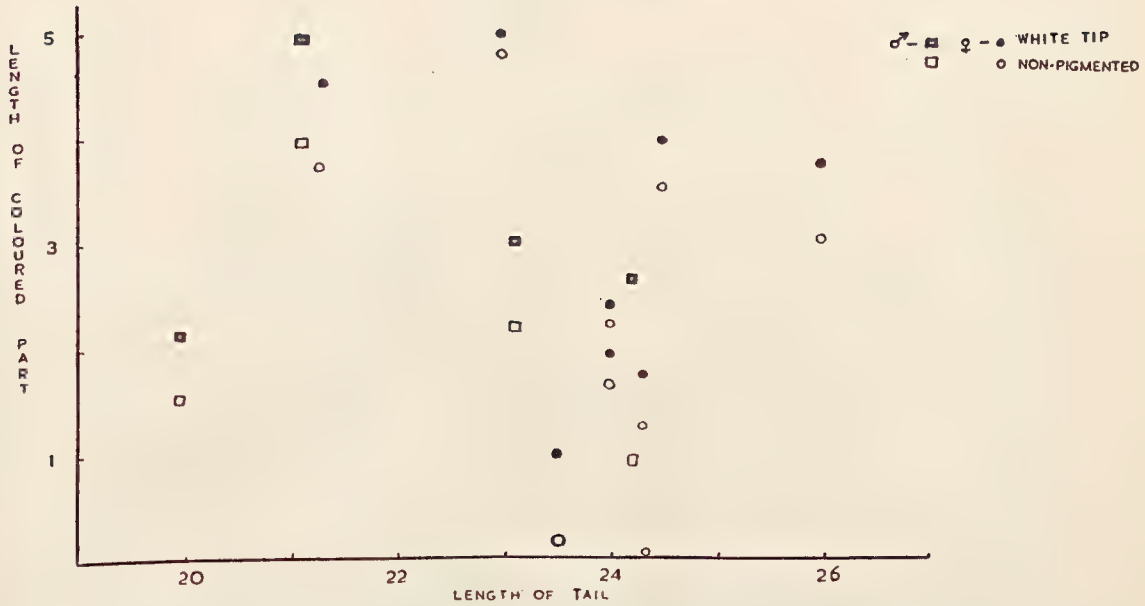


FIG. 2.—The length of the white tip in relation to the length of the tail (in cms.) in male and female *Potorous tridactylus*.

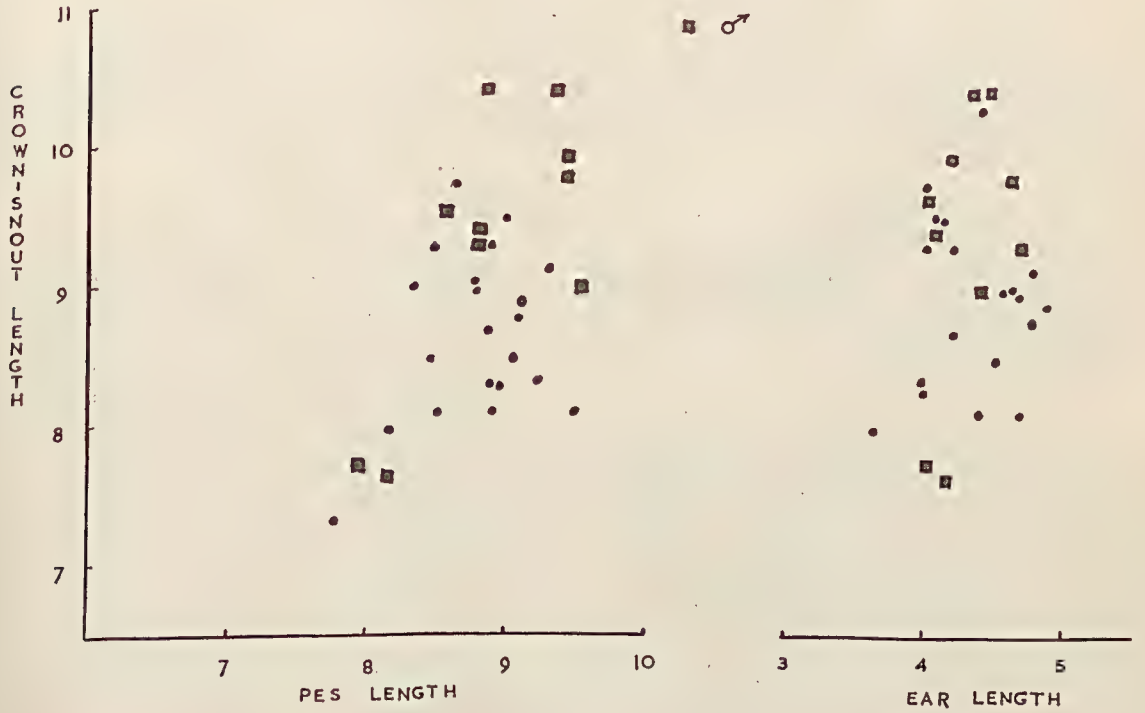


FIG. Length of head (in cms.) in relation to the length of th e foot and the length of ear in *Potorous tridactylus*.

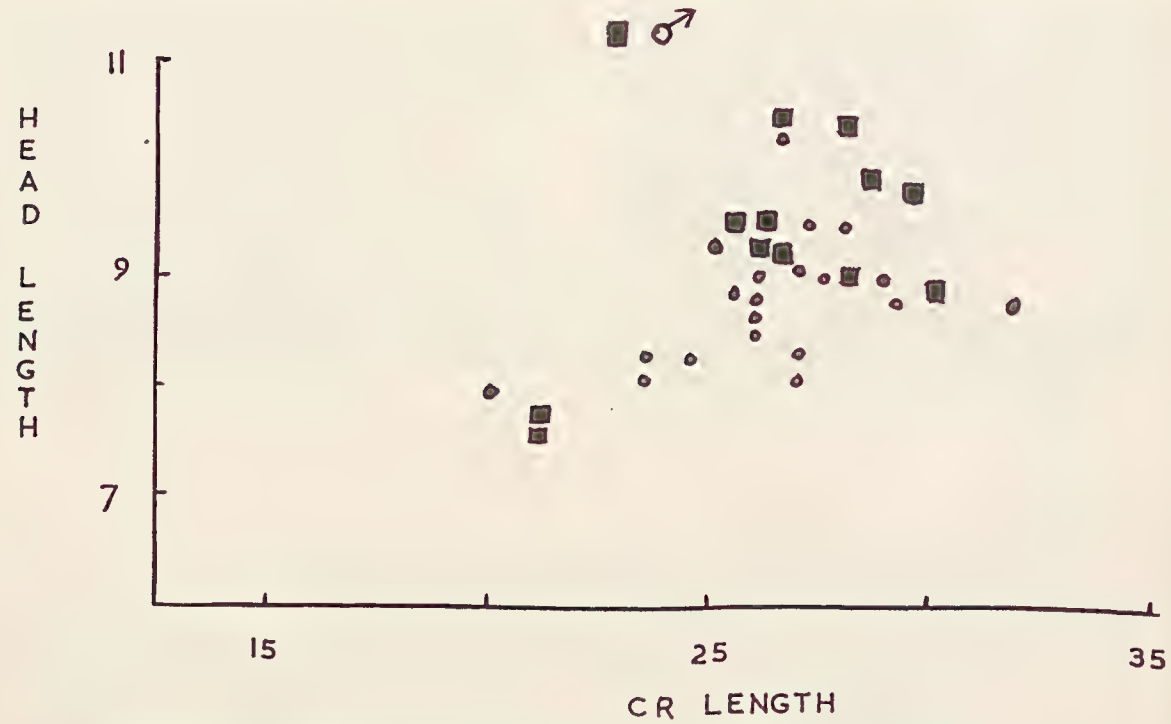


FIG. 4.—Length of head in male and female *Potorous tridactylus* plotted against CR. length.

## FOOT

The foot of the Potoroo resembles that of the other macropods and has two syndactyl toes. The sole of the foot is naked and granular. The digital formula is 4>5>2.3.

## MANUS

The manus possesses five digits but differs from that of the members of the subfamily Macropodinae in that the digits are of unequal length with the claws of the median digits greatly elongated. These claws are used in digging for roots and other food. The palms are naked and granular. This digital formula is 3>4>2>1>5.

## VIBRISSAE

The Potoroo has well developed facial vibrissae. The vibrissae of the Potoroo were described in detail by Lyne (1959), and only general comments are given below. There are three rows of mystacials, the first bearing one vibrissa though two are less commonly encountered. The second row bears four or rarely five vibrassae while the third row shows greater variation and may bear five or six. There usually are two genal vibrissae though one may be encountered. The interramal region has usually one vibrissa though two may rarely be encountered. The ulnar carpals are usually three in number though one, two or four are to be encountered. The only vibrissae which are constant in number are the two suproarbitals. The Potoroos have no anconeal, calconeal or medium antebrachial vibrissae, a feature which is shared with the other macropods.

## TEETH

The dental formula of the Potoroo given by Jones is $I\ \frac{1.2.3}{1.0.0}$; $C\ \frac{1}{0}$; $P.M.\ \frac{0.0.3.4}{0.0.3.4}$; $M\ \frac{1.2.3.4}{1.2.3.4}$. However, the small range of five skulls which are available to me shows only one premolar present and it is apparent that there must be some variation in this feature. The upper incisors are weak compared to those of the kangaroos but the lower pair are long and powerful. The first pair of upper incisors are the largest and strongest teeth of the upper jaw but the second and third pairs are very small. The canine teeth are recurved and strong, the premolars are strong and grooved. Bensley (1903) described the New South Wales representatives of the species as having three grooves on the premolars while the Tasmanian animals were said to have three grooves with indications of a fourth. Bensley went on to describe only 3 grooves as occurring on the teeth of "the dwarf *P. rufus*," but this species is now accepted as being a young *P. tridactylus*. In the Tasmanian specimens examined there may be three or four grooves on the premolars, the grooves on the inside of the tooth may be more developed than on the outside. The grooves appear to be better developed on the lower premolars than

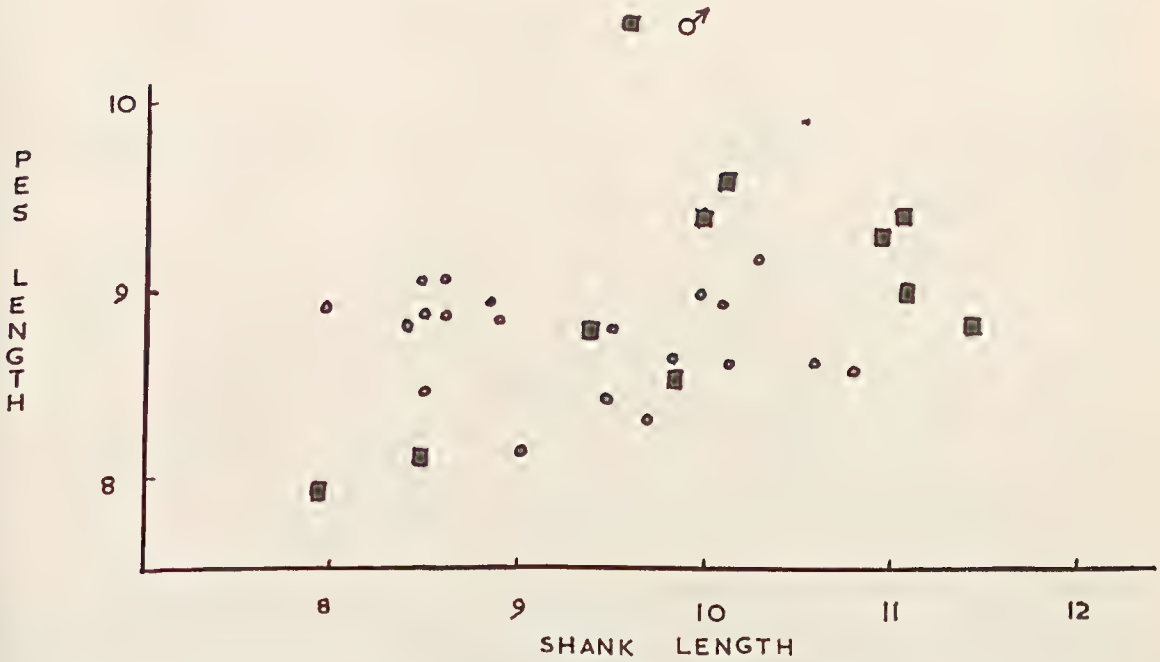


FIG. 5.—Length of shank (in cms.) in relaiton to the length of the foot in 33 *Potorous tridactylus*..

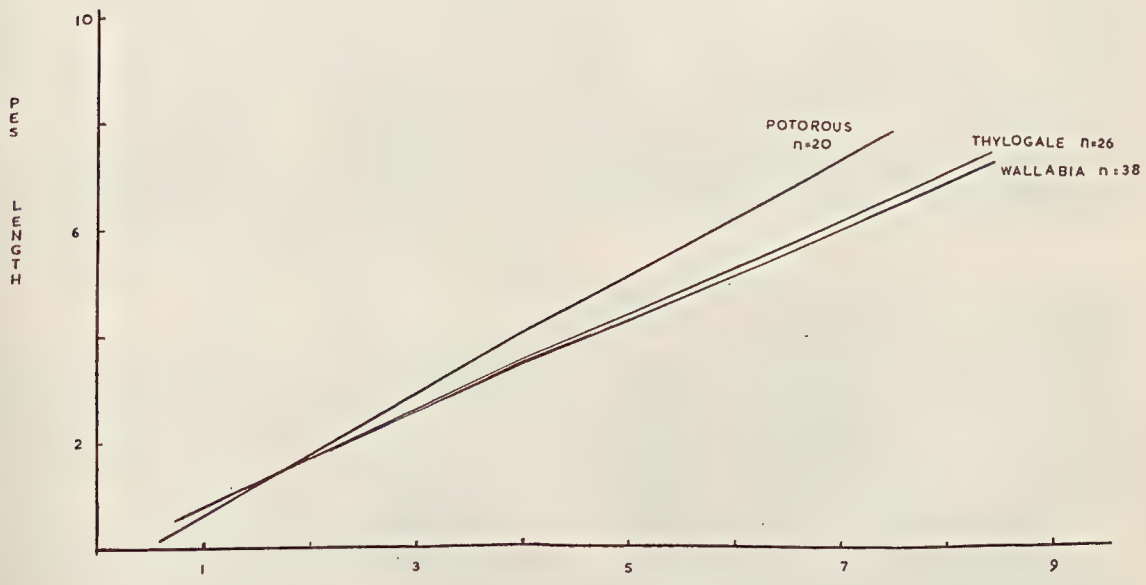


FIG. 6.—Length of shank (in cms.) to length of foot in *Potorous tridactylus*. *Thylogale billardierii* and *Wallabia rufogrisea*.

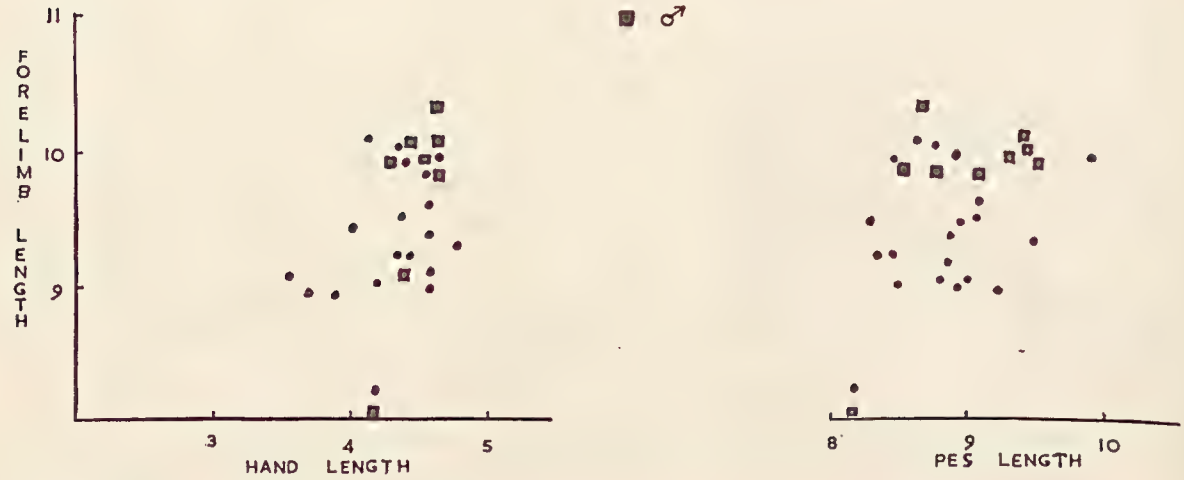


FIG. 7.—The length of forelimb (in cms.) in relation to the length of hand and length of foot in 27 *Potorous tridactylus*.

on those of the upper jaw. It is doubtful if the possession of four grooves is associated with old age since two male skulls of breadth 48.0 and 46.2 mms. show 3 or 4 grooves respectively. The premolar grooves are not as strongly developed as in *Bettongia*.

The molars are four in number, are robust and the three anterior teeth of the upper jaw are subequal in size to their companions in the same jaw as well as to those of the lower ramus. The 4th molar in the upper jaw is smaller than 1-3 but is subequal to its fellow of the dentary.

Examination of 20 live specimens showed that all individuals possessed two premolars and no sexual differentiation could be observed in the distribution of grooves on the teeth.

The teeth of *Potorous* are not as specialized as those of the Macropodinae in that they retain more of their insectivorous form, especially in the premolars and molars.

## POUCH

The pouch of the female is well developed and opens forward. The aperture, which is situated about one third of the length of the belly from the posterior end, can be detected by a brownish stain on the fur. The pouch can be identified at the birth of the animal (Guiler, 1960). It contains four nipples arranged in an anterior and posterior pair, each situated to the left and right of the midline. Multiparous females have one or more nipples larger than the others due to the feeding activities of the young.

## BODY FORM AND PROPORTIONS

The body (Plate 1) is squat and ungainly. The hindquarters are large but the legs are not greatly elongated as in many members of the Macropodidae. The forequarters are lightly built and the forelegs are much smaller than the hind, giving an unbalanced appearance to the animal when it is on four feet. The head is disproportionately large in relation to the forequarters. The ears, eyes and tail, together with the vibrissae, have been described above.

Male Potoroos have a slightly longer head than females of similar size. This feature can be seen taking either pes length or ear as an index of size (Fig. 3), or the crown-rump length (Fig. 4). The same feature is shown when the length of the head is plotted against the size of the ear. It has been shown earlier (Guiler, 1960) that the ear grows rapidly in the pouch young to 3.75 cm. length at 280 days of age and thereafter it grows slowly to an average adult length of 4.35 cms. and it can be taken as a structure against which the growth of other organs can be plotted. It is difficult to distinguish the sexes of Potoroos by the measurement of proportions of the body, but with experience in the field it is possible to guess the sex of a Potoroo with reasonable, though not infallible, accuracy, the males being more heavily built than females.

The length of the hind foot plotted against the crown-snout length shows that these two lengths are directly proportional to each other, and that the foot is sub-equal to the crown-snout length. The foot in adult animals apparently does not keep on growing throughout the life of the individual since there is no evidence of larger animals having big feet. In fact, the maximum foot length of a Potoroo appears to be about 9.5 cms.

The foot is slightly shorter than the shank though some animals have the shank almost the same length as the foot (Fig. 5) and a few have the foot shorter than the shank. The small sample measured (33 animals) shows that the males have

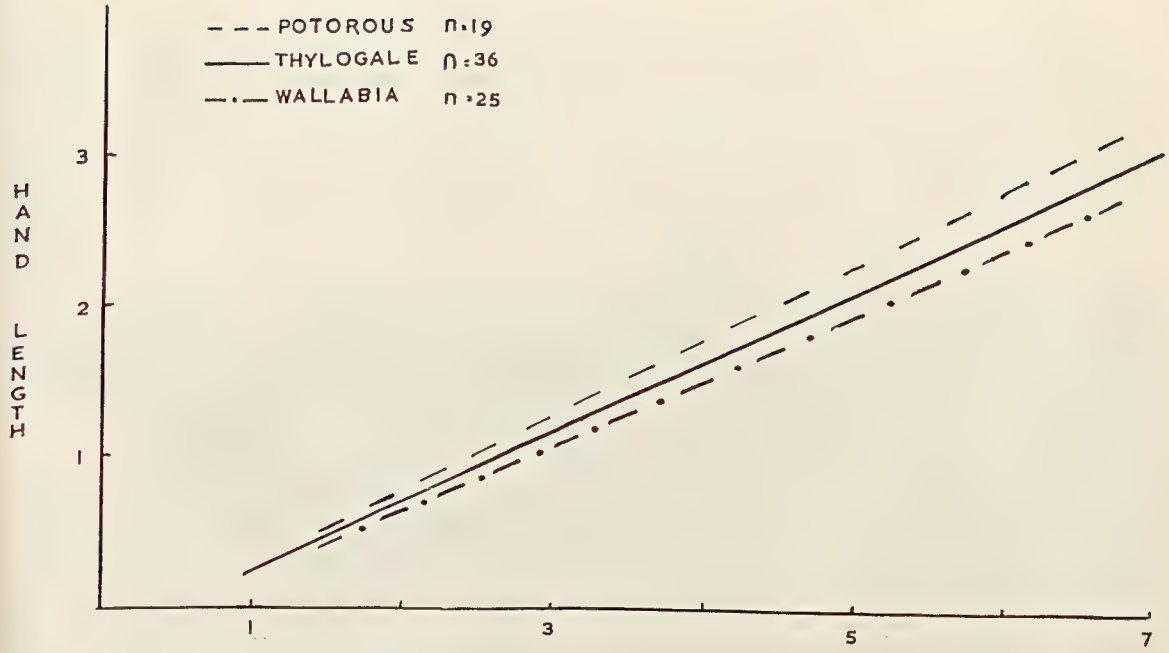


FIG. 8.—The length of the hand plotted against the length of forelimb in *Potorous tridactylus*, *Wallabia rufogrisea* and *Thylogale billardierii*.

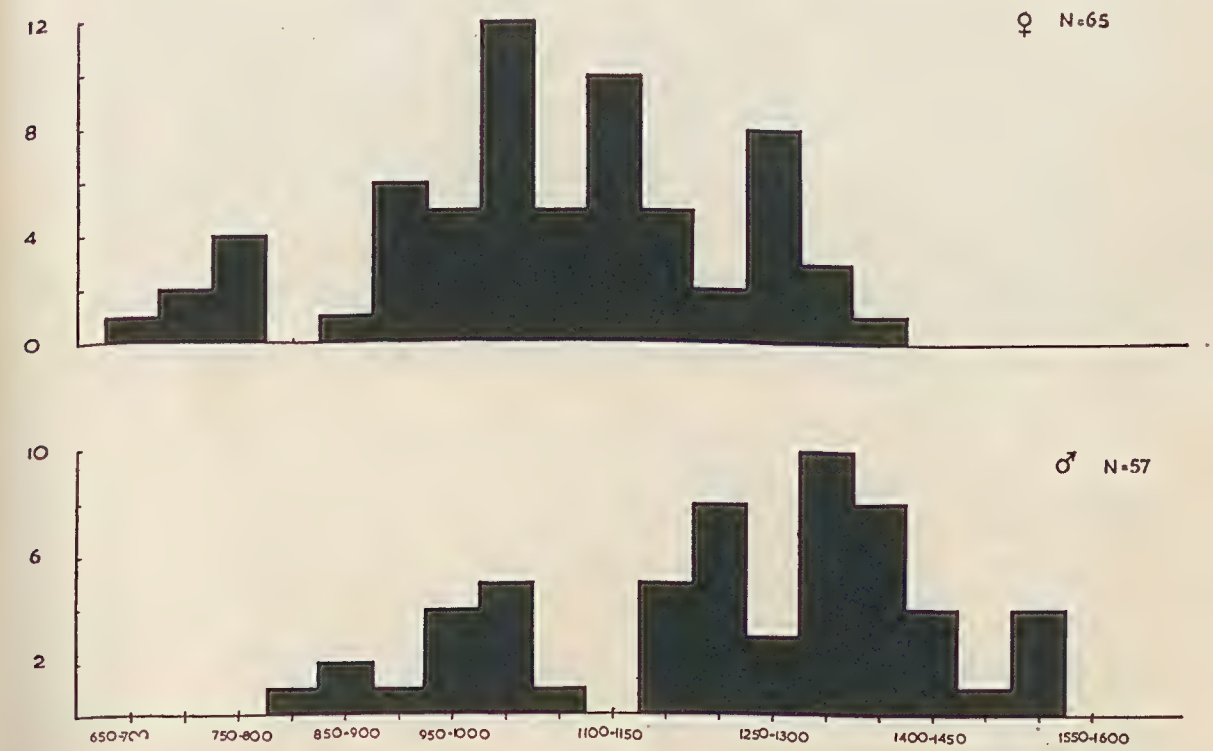


FIG. 9.—The body weight (in grams) of 122 living *Potorous tridactylus*. The lower and upper histograms show the weights of females and males respectively. The weights were classified respectively into 50 gram groups.

a greater mean foot than the females, being 8.2 cms. to 7.95 cms. respectively and the shank also is longer in the male measuring 10.07 cms. to 9.9 cms. The shorter leg of the female may in part account for the lighter build of the female.

Comparison of the length of the foot plotted against length of shank in the Potoroo, the pademelon *Thylogale billardierii* (Desmarest) and the wallaby, *Wallabia rufogrisea* (Desmarest) shows that the relation of these two parts of the hind limb to each other is the same in both *Thylogale* and *Wallabia*, but in the Potoroo the foot is relatively slightly longer than in the other two species (Fig. 6).

The males have a slightly shorter forelimb than the females, though there is little difference in the length of the manus in either sex (Fig. 7). Similarly, the length of the forelimb in the male relative to the length of the foot is greater than in the female.

The length of the hand in relation to the length of forelimb in *Potorous* is slightly greater than the measurement in both *Wallabia rufogrisea* and *Thylogale billardierii* (Fig. 8). In the latter two species the relationship is the same.

## SEXUAL DIMORPHISM

Apart from the presence or absence of a pouch or testes, the difference between the sexes is very slight. The head of the male is slightly longer and broader than that of the female and the body is more heavily built and larger in size and is of greater weight.

## BODY WEIGHT

The live weight of adult *Potorous* was measured when the animals were first captured and these weights are graphed in Fig 9. In this figure the weights of female animals which were less than 650 grs. have been ignored since these are obviously juvenile individuals which had recently left the mother. In the case of males, the comparable weight selected was 800 grs. The histograms show that the males are heavier than females and that probably two weight groups can be identified in the population, namely a sub-adult and an adult. The weights of these groups are below 800 grs. in the femae and below 1050 grs. in the male. These weight groups do not give an accurate age for individuals in the population beyond the broad outline mentioned above since it is known from earlier work that Potoroos live to 5 years in a natural state (Guiler, 1957).

The higher weights for males shown in the histogram end abruptly, thus indicating that the larger males had not been captured. This may be due to a sampling error or to the animals being too large for the type of trap used in the field work.

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Plate 1.—Adult female *Potorous tridactylus*, with young.

# OBSERVATIONS ON SOME TASMANIAN FISHES: PART X

By

E. O. G. Scott

(With three text figures)

## ABSTRACT

Two species, *Lissocampus caudalis* Waite and Hale, 1921, and *siphonognathus argyrophanes* Richardson, 1858, are added to the Tasmanian faunal list: the brood pouch of, and dermal tentacles in, the first-named species are now first described and figured. Miscellaneous observations are made upon the following: *Parascyllium multimaculatum* Scott, 1935 (description of second recorded individual, a virtual topotype; comparison with holotype; figure of oral region): *Callorhynchus milii* Bory de St. Vincent, 1823 (egg cases: distribution of a large sample along a beach, specification of size and coloration in a sample of this population): *Muraenichthys tasmaniensis* McCulloch, 1911 (proportions, coloration, incidental correction to earlier key): *Macrorhamphus scolopax* (Linné), 1758 (occurrence in Tasmania confirmed; account of specimen): *Notopogon endeavouri* Mohr, 1937 (general account of a local example, with figure): *Syngnathus curtirostris* Castelnau, 1872 (position on local list): *Aldrichetta forsteri* (Valenciennes), 1836 (sample with two size classes; contrasted with unimodal sample of *Arripis trutta* (Bloch and Schneider), 1801 in same haul). General surveys are made of the position of Tasmania of the families Macrorhamphosidae and Syngnathidae; keys to the local representatives are provided for these and for Orectolobidae, Mugilidae, Siphonognathidae.

In view of the importance attachable to the Handbook of Australian Fishes (Munro 1956+), now in course of serial publication through the monthly *Fisheries Newsletter*, our material has been systematically checked against the Handbook specifications, and attention has been called to any divergences met with.

## INTRODUCTION

This paper follows the general plan of earlier contributions under the same title. Among established conventions are these: standard length, total length are denoted by *Ls, Lt,* respectively; unless otherwise stated, linear dimensions are regularly given in millimetres, the name of the unit being customarily omitted; locality specifications include county name. Conventions for the presentation of synonymy follow in general the recommendations of Schenk & McMasters (1956). Symbols here introduced in connexion with proportional dimensions are *TLs,* thousandths of standard length; *TLt* thousandths of total length: similarly for hundredths, *HLs, HLt* are available.

Basic data is at all points compared with that presented in the Handbook of Australian Fishes. Comprehensive surveys of the Australian fish fauna as a whole are few: Macleay's Descriptive Catalogue of the Fishes of Australia (1881) with Supplement (1886), based largely on Günther's British Museum Catalogues, and giving generic and specific diagnoses, with geographical distribution; McCulloch's (1929) A Check-List of the Fishes Recorded from Australia; The Fishes of Australia (Whitley, 1940), of which only the first volume (covering elasmobranchs, holocephalans, dipnoans, cyclostomes, cephalochordates; with illustrations) has so far appeared; the Handbook of Australian Fishes (Munro 1956 +), now in course of serial publication through the monthly *Fisheries Newsletter,* issued by the Department of Primary Industries, Canberra, which gives specific diagnoses, accompanied by figures. In view of the importance of Mr. I. S. Munro's new work, first, as the most up-to-date survey of our present knowledge in this field, secondly, as a probable standard of reference over a considerable period, it has been thought expedient to check our material, item by item, against the Handbook specifications, and to call attention to any divergences encountered—perhaps the most significant contribution occurring in the Syngnathidae, where an examination of a fair amount of material has led, in a number of instances, to some extension in range of meristic and other metrical criteria.

### Family Orectolobidae

Five species recorded from Tasmania: (1) *Orectolobus* Bonaparte, 1843, (*a*) *O. maculatus* (Bonnaterre), 1788, recorded from all Australian States; (2) *Parascyllium* Gill 1862, (*b*) *P. variolatum* (Duméril), 1853, Victoria, South Australia, southern Western Australia, Tasmania, (*c*) *P. collare* Ramsay and Ogilby, 1888, New South Wales, Victoria, Tasmania, (*d*) *P. ferrugineum* McCulloch, 1911, Victoria, South Australia, Tasmania—the Tasmanian record by Olsen (1958) postdates McCulloch (1929), Whitley (1940), and Munro (1956), (e) *P. multimaculatum* Scott, 1935, Tasmania.

### Key to Orectolobidae Recorded from Tasmania

Origin of anal behind origin of second dorsal (anal usually wholly behind second dorsal; continuous or subcontinuous with caudal). Spiracle in wide oblique slit .... .... .... .... .... .... *Orectolobus*

1 { Body broad, flattened. Anterior teeth long, sharply pointed. About seven weed-like appendages on either side of head. Brown: large spots, with conspicuous white annulus, on body; light spots on all, or most, fins .... .... .... .... .... .... .... *O. maculatatus*

Origin of anal in advance of origin of second dorsal (anal just in advance of, or partly, under second dorsal; separated from caudal by interval exceeding anal base). Spiracle not in wide oblique slit; minute .... *Parascyllium*: 2

2 Origin of first dorsal behind middle of total length. Posterior margin of first dorsal excavate .... .... .... .... .... .... .... .... .... .... .... .... *P. multimaculatum*

Origin of first dorsal not behind middle of total length. Posterior margin of first dorsal rounded or truncate .... .... .... .... .... .... .... .... 3

3 Body with numerous white spots. All, or most, fins with several blackish blotches. A well-defined dark nuchal band with numerous (scores of) white spots .... .... .... .... *P. variolatum*

Body without numerous white spots, but with fairly evenly spaced large brown spots. All, or most, fins with one or several brown spots. An indistinct darkish nuchal band, without numerous white spots, but with a small number of (about three) dark spots on each side .... .... .... .... .... .... .... .... .... .... .... .... *P. ferrugineum*

## Genus **PARASCYLLIUM** Gill, 1862

### *PARASCYLLIUM MULTIMACULATUM* Scott, 1935

(Text figure 1.)

*Parascyllium multimaculatum* Scott, 1935, *Pap. Proc. Roy. Soc. Tasm.*, 1934: 63, pl. v, fig. 1. Type locality: Tamar Heads [Devon/Dorset], Tasmania.

*Parascyllium multimaculatum* Scott. Whitley, 1940, Fishes of Aust., I: 77, fig. 64. Munro, 1956, Handbk Aust. Fish.: 4, fig. 22 [instalment No. 1 in *Fisheries Newsletter*, XV, 7, July 1956: 16, fig. 22].

*Virtual topotype.*—The species appears to have remained unrecognized for a quarter of a century: considerable interest is thus attached to the capture of a second individual, netted, near rocks, at Green's Beach, Devon, by Mr. H. L. von See on 10th April, 1957 (Q.V. Mus. Reg. No. 1957.5.16). This specimen is a virtual topotype—Green's Beach is the sea-beach beginning immediately at, and extending several miles westward from, the western bank of the Tamar (type locality: Tamar Heads): in some sharks, it has been found, the distribution is quite limited, and this may obtain here. It is of the same sex as the holotype (male), which it approaches very closely, both in dimensions (see Table 1) and in color pattern. In spirit, gutted.

*Dimensions.*—Some comparative dimensions of the two sharks are set out (in the first line in mm, elsewhere in thousandths of total length) in Table I; and some additional dimensions (in mm) of the present example are recorded in Table II.

*Mouth.*—The only published figure of the species (Scott, 1935: pl. v, fig. 1) shows the holotype in lateral aspect. The mouth was, unfortunately, not illustrated, and, the specimen being mounted, the omission could not subsequently be satisfactorily remedied: the ventral surface of the head of the Green's Beach individual is shown in text-fig. 1.

TABLE I

*Parascyllium multimaculatum* Scott, 1935. Dimensions of holotype male, Tamar Heads, Devon/Dorset, Tasmania, and male from Green's Beach, Devon, Tasmania. Actual dimensions in millimetres in first line: all other dimensions expressed as thousandths of total length.

| Dimension | Holotype | | Green's Beach Specimen | |
|---|---|---|---|---|
| Total length (mm) | 710 | | 713.5 | .... |
| Head: length to first gillslit; to fifth gillslit | 101 | 157 | .... | 158 |
| Eye: interorbital | 18 | 42 | 18 | 44 |
| Snout: preoral length | 48 | 13 | 44 | 14 |
| Spiracle: distance from eye; interspiracular distance | 14 | 68 | 12 | 65 |
| Nostril: internarial distance | 25 | | 27 | |
| Length (chord) of gillslit: first; second | 8 | 10 | 10 | 12 |
| Length (chord) of gillslit: third; fourth | 11 | 11 | 13 | 13 |
| Length (chord) of gillslit: fifth | 37 | | 29 | |
| Pectoral: length to origin; length of fin | 142 | 86 | 141 | 88 |
| Pectoral: length of base; total spread | 46 | 273 | 48 | 275 |
| First dorsal: length to origin; base | 507 | 56 | 504 | 56 |
| First dorsal: vertical height | 68 | | 68 | |
| Interdorsal | 142 | | 140 | |
| Second dorsal: length to origin; base | 706 | 56 | 708 | 56 |
| Second dorsal: vertical height | 59 | | 60 | |
| Pelvic: length to origin; length of inner border | 372 | 94 | 367 | 95 |
| Clasper: medial length of main cartilage | 82 | | 79 | |
| Anal: length to origin; base | 638 | 65 | 641 | 65 |
| Anal: vertical height | 30 | | 34 | |
| Caudal: length to origin; inferior lobe; superior lobe | 804 | 820 | 804 | 813 |
| Caudal: maximum depth | 45 | | 47 | |
| Depth: at origin of first dorsal; at origin of second dorsal | .... | 37 | 50 | 39 |
| Depth: maximum | 91 | | .... | |
| Width: at origin of first dorsal | 49 | | 50 | |

TABLE II

*Parascyllium multimaculatum* Scott, 1935. Additional dimensions (mm) of virtual topotype male, supplementing data in Table I.

| Dimension | mm | |
|---|---|---|
| Mouth, width: cleft; between outer labial borders | 34 | 35 |
| Mouth, length of level of rictus | 15 | |
| Pectoral, direct length from tip to: superior insertion; inferior insertion | 61 | 72 |
| Pectoral, maximum width (normal to longitudinal axis) | 51 | |
| First dorsal, length (direct) of border: anterior; posterior | 61 | 36 |
| First dorsal, length (direct) of border: inferior | 22 | |
| Second dorsal, length (direct) of border: anterior; posterior | 60 | 31 |
| Second dorsal, length (direct) of border: inferior | 18 | |
| Anal, length (direct) of border: anterior; external | 47 | 35 |
| Anal, length (direct) of border: internal | 8 | |
| Caudal: depth at notch; maximum depth caudad of notch | 15 | 24.5 |
| Caudal, distance behind inferior origin to maximum depth | 46 | |
| Vent: length to enterior border; anteroposterior length | 28.5 | 7 |
| Nostril, length to: anterior border; posterior border of nasal cavity | 7 | 12 |
| Nostril, length to tip of nasal cirrus | 14 | |

Family CALLORHYNCHIDAE.

Meuschen's genus was spelt *Callorynchus*: this is generally amended to conform to the standard spelling of *rhynchos*, a beak; with the family name adjusted correspondingly.

## Genus **CALLORHYNCHUS** Meuschen, 1781

### *CALLORHYNCHUS MILLII* Bory de St. Vincent, 1823

*Callorynchus milii* Bory de St. Vincent, 1823, Dict. Class. d'Hist. Nat., iii: 62, pl.v. Type locality: 'Cotes occidentales de la Nouvelle Hollande'.

*Egg cases; abundance.*—While not exactly rare, the characteristic egg cases are certainly not common objects on most Tasmanian beaches. In May, 1959 the writer found empty egg cases were abundant, over a stretch of some seven-tenths of a mile, at Beauty Point, Devon, on the River Tamar, approximately eight miles from the sea. Empty cases collected on 16th May on 300 yards of beach numbered 410. The next day the search was extended upstream for 300 yards (at which point swampy land was encountered, making collecting impracticable) and downstream for 600 yards—counts being recorded at 25-yard intervals: also, on two subsequent days the original 300 yards was worked over. In all the search yielded 994 specimens. The results are summarized in Table III: it will be observed that the highest concentration, 1.09 eggs per linear yard of beach-line, falls sharply upstream; the decrease seaward being much more gradual, with the plot of abundance against distance here virtually linear.

All the specimens were picked up on a rather (at times decidedly) narrow sandy strip, riverward from which the beach extended as a flat, in part rock-strewn, but chiefly consisting largely or wholly of mud, for a distance (greatest near the middle of the stretch examined) of up to several hundred yards. I was informed egg cases are to be found in this region in abundance at almost any time: on a subsequent visit to Beauty Point I again observed large numbers here. Some residents use them as garden manure. It would seen probable that this species—the females of which have been reported to carry a pair of eggs protruding from the oviducts for some time before laying them (Whitley, 1940: 237)—breeds freely in close proximity to the site at which the material was secured.

*Egg cases; size.*—Five measurements carried out on 50 examples taken at random are specified in Table IV. Total length is the largest measurement, between parallels, including the fine terminal filaments: hard length omits the filaments (finger pressed lightly against end to determine measurable terminal point): formal length is taken, between parallels, from level of inner ends of paired slits (usually some 2 cm long), found between the distal portion of the longer pipe and the adjoining float, to the further end of the oval portion of the capsule, as defined by a change in color where the primary inflation ends rather abruptly.

Three points of interest brought out by the table may be noted. (*a*) For all measurements the coefficient of variation is, to nearest integer, 7—this conforms to expectation based on magnitudes encountered in related fields (see Simpson and Roe, 1939; Haldane, 1952; Scott, 1953). (*b*) The mean value, for the three modes of measuring the length of the percentage of entries, occurring within the range $\bar{x} \pm \sigma$ is 66, a good approximation to the 68.3 of the normal distribution. (*c*) The values of range $\sigma$ do not differ greatly from those expected on a normal distribution (for $n = 50$: mean 4.50; $P = 0.05$, 5.64; $P = 0.01$, 6.23).

An examination of the correlation coefficients for the various measurements in relevant pairs shows: a closer correlation of width of egg capsule with hard length ($r = 0.26$) and with formal length,

*i.e.*, hard length of capsule plus most of longer process (0.24), than with total length (0.18); a much greater correlation of total length with hard length (0.94) than with formal length (0.62); a noticeably more marked correlation of total width with width of egg capsule (0.52) and with hard length (0.51) than with either total length (0.40) or formal lengh (0.31).

*Egg cases; color.*—The color varies considerably in different specimens and as often as not differs in parts of the one example: the range is mainly from black through blackish brown, brown, slaty green, olivaceous, dark green, to lightish green, greenish amber, and amber. The egg capsule with its associated processes is commonly darker than all, and is almost always darker than some part of, the float. Often a dark band flanks the capsule and at least the proximal portion of the processes, usually being separated from the margins of the longer pipe and from the one-third of the capsule at the base of the shorter pipe by a narrow lighter-colored or less-pigmented strip. The hair-like covering that extends over the whole of one surface (save for about two-thirds of the capsule at its end adjacent to the longer process; this region being almost always nearly or completely naked) may be lighter in color than its substrate.

Family ECHELIDAE

In a key to the Echelidae recorded from Tasmania (*Muraenichthys breviceps* Günther, 1876, M. *australis* Macleay, 1881, *M. tasmaniensis* McCulloch, 1911) given in an earlier contribution in this series (1953: 146) two entries are unfortunately transposed. The specification 'Interval between dorsal and anal origins about 1 in head' given for *M. australis* belongs to *M. tasmaniensis* and the correlate given for *M. tasmaniensis* belongs to *M. australis*. (That an error has occurred is, indeed, directly deducible from the text by a consideration of the two entries immediately following the reference letters B, BB).

Genus **MURAENICHTHYS** Bleeker, 1865

*MURAENICHTHYS TASMANIENSIS* McCulloch, 1911

*Muraenichthys tasmaniensis* McCulloch, 1911, Zool. Res. Endeavour, 1: 19, fig. 5. Type locality: Oyster Bay [Pembroke], Tasmania.

*Musaenichthys tasmaniensis* McCulloch. Munro, 1957, Handbk Aust. Fish.: 46, fig. 323 [instalment No. 11 in *Fisheries Newsletter*, XVI, 5, May, 1957: 16, fig. 46].

TABLE III

*Callorhynchus millii* Bory de St. Vincent, 1823. Numbers of egg cases collected on beach, Beauty Point, Devon, Tasmania, on stated dates in specified regions.

| Regions: In succession seaward | Length of region: yards | Number of egg cases collected: May, 1959 No entry denotes no collection made | | | | Number of eggs per linear yard collected on 17th |
|---|---|---|---|---|---|---|
| | | 16th | 17th | 18th | 20th | |
| A | 150 | .... | 24 | .... | .... | 0.16 |
| B | 150 | .... | 41 | .... | .... | 0.27 |
| C | 300 | 410 | 79 | 57 | 29 | 0.26 |
| D | 150 | .... | 163 | .... | .... | 1.09 |
| E | 150 | .... | 112 | .... | .... | 0.75 |
| F | 150 | .... | 64 | .... | .... | 0.43 |
| G | 150 | .... | 15 | .... | .... | 0.10 |
| Totals and mean .... .... | 1200 | (410) | 498 | (57) | (29) | 0.42 |

TABLE IV

*Callorhynchus milii* Bory de St. Vincent, 1823. Dimensions (mm) of 50 egg cases collected on beach at Beauty Point, Devon, Tasmania, May, 1959. For specification of dimensions see text.

| Dimension | Range | Mean | Standard deviation | Coefficient of variation | Percentage of entries within the range $\bar{X} \pm \sigma$ | Range/$\sigma$ |
|---|---|---|---|---|---|---|
| Total length .... .... .... | 202-285 | $239.9 \pm 2.5$ | $17.5 \pm 1.8$ | $7.5 \pm 0.8$ | 64 | 4.74 |
| Hard length .... .... .... | 181-247 | $215.4 \pm 2.1$ | $14.9 \pm 1.5$ | $7.1 \pm 0.7$ | 56 | 4.37 |
| Formal length .... .... .... | 104-147 | $129.0 \pm 1.3$ | $9.2 \pm 0.9$ | $6.9 \pm 0.7$ | 78 | 4.69 |
| Maximum width including float .. .... .... | 75-116 | $98.4 \pm 1.0$ | $7.1 \pm 0.7$ | $7.2 \pm 0.7$ | 78 | 5.81 |
| Width of egg capsule | 31-45 | $38.2 \pm 0.4$ | $2.6 \pm 0.3$ | $6.7 \pm 0.7$ | 76 | 5.47 |

*Specimen from Deviot.*—This fish is not frequently met with, and I know of no data on Tasmanian material other than the holotype, total length 170: the species is, however, now recorded also from Western Australia. A specimen, total length 198, from the Tamar River at Deviot, Devon, found dead and partly dried out on a rock by Miss S. Ashton, was received at the Queen Victoria Museum Launceston on 8th August, 1958.

*Some proportions (TLt).*—Length to: vent 414, origin of anal 422, origin of dorsal 480. Length of: eye 4.0, snout 15, head 81, mouth cleft 27. Interorbital 8.6. Depth (in parentheses width), as preserved, at: back of eye 11 (10), middle of branchial sac 23 (13), gill opening 21 (15), vent 20 (20). The fins were sunken into the mesial grooves and their height was not measurable.

*Schmidt's index.*—In the key mentioned above the entry for this species of Schmidt's index, $S = \frac{a-d}{t} \times 100$, where $a$ = length to vent, $d$ length to dorsal origin, $t$ = total length, is based, as there noted, on the holotype only. That value is —7.6; in the present specimen S = —6.6: both entries contrast well with the value for the type of *M. australis* (—2); in the other Tasmanian species, *M. breviceps*, S = +16-23.

*Coloration.*—In spite of its rather dried state the specimen yields some useful notes on coloration. There is a sharp line of demarcation on trunk and tail between the upper half, which is yellow, thickly studded with small brown chromatophores, and the lower half, which is clear pale yellow: ventral surface darker mesially than elsewhere. Head darker than body: whole of its dorsal surface dark, somewhat reddish brown deepest (and least red) on snout: lateral surface to level of back of eye dark brown (about concolorous with dorsum of snout), behind eye generally somewhat lighter, a state of affairs partly accounted for by the fact that the rather densely set small brown chromatophores that extend behind eye for about an eye-diameter fade out on most of rest of side of head (the chromatophores on lower jaw extend further caudad than those on cheek): ventral surface lighter than lateral. Branchial basket chiefly somewhat reddish brown.

### Family MACRORHAMPHOSIDAE.

Though the group is a small one, with only about half a dozen Australian representatives, earlier uncertainties regarding distribution and continuing developments in taxonomy have combined to keep the overall position of the family on Tasmanian lists in a continual state of flux: and it may well be that the last systematic word has not yet been said. The following survey accepts as basis for discussion the taxonomic position arrived at by Mohr (1937) in her *Dana* revision. This differs from what may perhaps be regarded as the currently accepted Australian view notably in three respects: first, the local *Macrorhamphosus elevatus* Waite is subsumed by Mohr in the cosmopolitan *M. scolopax* (Linné); secondly, she identifies as *M. velitaris* (Pallas) a fish having (as in the original description) 25 anal rays, whereas Weber & De Beaufort (1922), Munro (1958), and others identify it with the fish, with 18 anal rays, described by Gilbert as *M. hawaiensis*, reproducing Gilbert's figure (1905); thirdly, two species of *Centiscops* are recognized, instead of one. It is, indeed, by no means certain that Mohr's revision represents a final tidying-up—however, with the foregoing three points in mind, her taxonomic framework can be, if it is thought desirable, readily transformed in terms of local conventions.

Species entering the discussion are: (*a*) *Macrorhamphosus* Lacépède, 1803 (the original spelling, *Macroramphosus*, is retained by McCulloch (1929) and by Whitley and Allan (1958), but is by most authors amended as here: Mohr (1937:30) credits *Macrorhamphosus* to Regan, 1914 *a*); (1) *M. scolopax* (Linné), 1758; (2) *M. velitaris* Pallas (1770); (3) *M. gracilis* (Lowe), 1839; (4) *M. elevatus* Waite, 1899 (originally published as a variety, *M. scolopax* Linnaeus, var. *elevatus* Waite); (5) *M. gallinago* Ogilby, 1908; (6) *M. lancifer* Ogilby, 1910; (7) *M. robustus* Ogilby, 1910; (8) *M. mollieri* Whitley, 1930: (b) *Centriscops* Gill, 1862; (9) *C. humerosus* (Richardson), 1864; (10) *C. obliquus* Waite, 1911 (originally published as a variety, *C. humerosus* Richardson, var. *obliquus* Waite: Mohr recognizes, in addition to the typical subspecies, a second, *C. o. maculatus* Pozzi and Bordalé, 1936): (c) *Notopogon* Regan, 1914; (11) *N. lilliei* Regan, 1914; (12) *N. endeavouri* Mohr, 1937.

The changing composition over some fourscore years of the Tasmanian list is outlined below—the name by which a species was catalogued by the author concerned being followed by its equivalent in Mohr's revision (species names specified by the serial numbers of the preceding paragraph).

(A).—Allport MS: (1) (as *Centriscus scolopax*) = M (1). Morton Allport's list is the first known catalogue of Tasmanian fishes: unpublished MS in this Society's library.

(B).—Johnston, 1883: (1) (as *Centriscus scolopax*) = M (1). Though actually listing (1)—*fide Allport*—Johnston observes, 'It is questionable whether the Tasmanian species may not be *C. humerosus* Rich. I have not yet examined any local specimens.'

(C).—Johnton, 1891: (1) (as *Centriscus scolopax*) = M (1). Between (B) and (C) he had handled an example, 100 long, from Port Sorell [Devon], had received reliable reports of other specimens caught near the Leven River [Devon], and had written (1885: 254) 'All my doubts about its existence in Tasmania are now set at rest.'

(D).—McCulloch, 1911: (4) = M (1): the determination of the M equivalent of (9) calls for discussion, Mohr observing, 'McCulloch lumps together several species and one cannot satisfactorily determine which of his 18 animals belong to the several species and localities: both the figured examples certainly do not belong, the others probably do not belong, to *Centriscops humerosus* Rich . . .' Of the figured specimens, one (fig. 9: 25), the smallest in the whole collection, 70 long, was secured, as is found by collating (D) and (E), 'Off Storm Bay, Tasmania'; the other, the largest

in the series, 265 long (length given later, in (E), as 270), which is the subject of pl. v, came from 'Sixty miles south of Cape Everard, Victoria, 60-70 fathoms'. These two individuals were re-described in (E) ,being there referred to (11). By including the entry for (D) without qualification in her synonymy of (12), Mohr may be assumed to have accepted both these specimens as belonging to her species: however, an earlier entry in her synonymy, citing (D), shows some confusion, since parts of two separate illustration-references are given, 'pl. v, fig. 9', while (contrary to her usual practice) only one length is noted. We may certaily write (9) (part.) = M (12); and may suggest (9) = M (12) + M (11) ? + M (9) ?? The material dealt with in (D) is of course only that in the *Endeavour* collections, and does not constitute an Australian or Tasmanian family list.

(E).—McCulloch, 1914: (9) = M (10), (11) = M (12). No Tasmanian record for (9): (11) is the same material identified in (D) as (9).

(F).—Lord, 1923: (4) = M (1), (9) = M (10) (probably), (11) = M (12). See comments on (G).

(G).—Lord & Scott, 1924: (4) = M (1), (9) = M (10), (11) = M (12). No actual Tasmanian records of any of the three species are given—simply references: (4) to Waite (1899:59), (9) to McCulloch (1914:90), (11) to McCulloch (1914:91). It seems possible that Lord (1923), who in this paper does not cite references (or records), wrongly picked up (9) as Tasmanian from (D)—what was there given as (9) really being a *Notopogon*: re-identified in (E) as (11), now identifiable as (12)—and missed the re-identification in (E), and that in the compilation of Lord & Scott (in which the Fishes were handled by Lord) references were just formally added to the pure name-catalogue (F). It is, of course, not impossible that (9) may occur here, but I am much inclined to believe the entry in Lord & Scott is a formal one unsupported by any definite record.

(H).—McCulloch, 1929: (2) = M (2), (3) = M (3) (though this species is not regarded by Mohr as Australian), (4) (with (5), (6), (7) as synonyms) = M (1) (with same species as synonyms), (9) (with (10), listed as a variety, as a synonym) = M (9) + M (10), (11) = (12). The Check List records as Tasmanian (4) = M (1), (11) = M (12).

(I).—Mohr (1937) gives (1) (with (4), (5), (6), (7), (8) as synonyms), (9), (10), (11), (12). Of these she would apparently regard as Tasmanian (1) (British Museum specimen, 110 long, from Tasmania from Morton 'Allpoch' = Allport, noted), (3), (12).

(J).—Munro, 1958: (3) = M (3), (4) = M (1), (9) = M (9) + M (10), M 11—as regards record, this entry = M (11) + M (12); but the figures (two) both numbered 657, on p. 94—reproductions from D, fig. 9, p. 25, and pl. v—refer to (12). The Handbook gives as Tasmanian (11); curiously omitting (4) = M (1).

(K).—Whitley and Allan, 1958: (4) (with (5), (6), (7) as synonyms) = M (1) (with same species as synonyms), (11) = M (11), (12) = M (12).

The standing on the Tasmanian faunal list of the 12 species listed above may be summarized thus:

The five species (1), (4), (5), (6), (7) appear clearly to represent a single form, regarded by Mohr as (1), by most Australian authors as (4). Though Tasmania is omitted from the Handbook's localities, the species undoubtedly occurs here—Tasmanian specimens noted, see above, by Johnston (1885), (D), and by Mohr (1937) (I), the last-noted individual probably being that mentioned by Regan (1914 *b*: 19): two local examples are discussed below.

Species (2) is not reported from Tasmania by Australian authors generally. Mohr (1937: 34) lists a specimen from 'zwischen Tasmanian und Australien', but the latitude and longitude cited (37° 05′ S., 159° 05′ E.) locate a point just off the New South Wales coast, near Eden: in her distribution chart (fig. 31: 61) she shows it as occurring along the Island's north coast, and eastward of its east coast (flanking here the coastal distribution of (1)).

Species (3) and (8): no Tasmanian records (unless, indeed, (8) is, as Mohr holds, a synonym of (1)).

The species entered in the local lists (F) and (G) as (9) is probably (10); but reasons for doubting that an actual Tasmanian record is involved have been given above. Neither (8) nor (9) is regarded as Tasmanian by Australian authors—most of whom recognize only (9)— or by Mohr.

(K) gives for (11) New Zealand, Tasmania, South and south-western Australia. Since (E), (F), (G), (H), (J) do not distinguish between (11) and (12), it is not possible to say whether their entries refer solely to 12 (which is the one species to which the basic reference, (E), undoubtedly relates) or to both (12) and (11).

The Tasmanian occurrence of (12) is guaranteed neither by (E) and its derivative references nor by (I). However, Whitley and Allan (1958:71) state, 'Off Tasman Head a trawler in March, 1914 caught 17,920 specimens of this species . . . their number was calculated by bucketsful and these buglers comprised the whole catch . . .'. A specimen from our east coast is dealt with below.

## Key to Macrorhamphosidae that occur, or have been thought to occur, in Tasmania

| | | |
|---|---|---|
| 1 | Lateral line absent. No patch of bristles on head or nape .... .... .... .... .... .... .... .... .... .... | 2 |
| | Lateral line present. A patch of bristles on head or nape (at any rate in adult) .... .... | 5 |
| | First and second dorsals continuous, or subcontinuous. Head and body with small non-contiguous spicular scales, each with transverse ridge or spine .... .... .... .... .... .... .... | 3 |
| 2 | First and second dorsals separate; the interdorsal ≥ base of second dorsal. Head and body with more or less contiguous scales, in each of which is embedded a keeled rhombic bony plate .... .... .... .... .... .... .... .... .... .... | 4 |

Second dorsal spine straight. Supraorbital rim feebly denticulate. Less humped; height of dorsal profile above front of pectoral base ≐ 2/3 snout. Unicolorous .... .... .... *C. humerosus*

3 Second dorsal spine slightly proconvex. Supraorbital rim strongly denticulate. More humped; height of dorsal profile above front of pectoral base ≐ snout. With 5-6 oblique bars (*C. o. obliquus*) or with 20-60 dark spots (*C. o. maculatus*) .... .... .... .... .... .... .... .... .... .... *C. obliquus*

As these species are understood by Mohr (1937), *Macrorhamphosus scolopax* (of which, in the view of most Australian authors, *M. elevatus* is the Australian correlate) and *M. velitaris* are separable thus:

Anal rays ≦ 19. Diameter of eye > postorbital portion of head .... .... *M. scolopax*

Anal rays = 25. Diameter of eye < postorbital portion of head .... .... .... *M. velitaris*

4 As these species are understood by Munro (1958), *Macrorhamphosus elevatus* (which Mohr synonymizes with *M. scolopax*) and *M. velitaris* are separable thus:

Origin of second dorsal spine nearer to caudal base than to head. Body deeper. Third dorsal spine usually > 3 in second dorsal spine. Brick-red above, violet bronze below .... .... .... .... .... .... .... .... .... .... *M. elevatus*

Origin of second dorsal spine nearer to head than to caudal base. Body shallower. Third dorsal spine usually < 3 in second dorsal spine. Mostly silvery, darkish on top of head and on back .... .... .... *M. velitaris*

Membrane of spinous dorsal weak, naked. Second dorsal spine inserted behind middle of total length without head; its length usually < 6 in total length. Bristle-patch extending to, or caudad of, level of opercular margin. Head > height of body. Of height of body at ventral origin, ≐ ½ above body-axis .... .... .... *N. lillei*

5 Membrane of spinous dorsal firm, scaly. Second dorsal spine inserted in advance of middle of total length without head; its length usually > 6 in total length. Bristle-patch not extending to level of opercular margin. Head ≦ height of body. Of height of body at ventral origin, ≐ 3/5 above body-axis .... .... .... .... .... .... .... .... .... .... *N. endeavouri*

## Genus **MACRORHAMPHOSUS** Lacépède, 1803

### *MACRORHAMPHOSUS SCOLOPAX* Linné, 1758

*Centriscus scolopax* Linné, 1758, Syst. Nat., ed. 1: 329. Type locality: North Atlantic and Mediteranean.

*Centriscus scolopax* Linné. Allport MS. Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.*, 1882: 123; 1885, ibid., 1884: 254; 1891, ibid., 1890: 34.

*Macrorhamphosus scolopax* Linnaeus var. *elevatus* Waite, 1899, *Mem. Aust. Mus.* iv: 59, pl. vii, fig. 1.

*Macrorhamphosus gallinago* Ogilby, 1908, *Proc. Roy. Soc. Qld* xxi: 92.

*Macrorhamphosus lancifer* Ogilby, 1910, New Fish. Qld Coast: 90.

*Macrorhamphosus robustus* Ogilby, 1910, New Fish. Qld Coast: 91.

*Macrorhamphosus elevatus* Waite. McCulloch, 1911, Zool. Res. Endeavour, I, 1: 23, text-fig. 8. Regan, 1914, *Ann. Mag. Nat. Hist.* (8), viii, 73: 17. Lord, 1923, *Pap. Proc. Roy. Soc. Tasm.*, 1922: 65. Lord and Scott, 1924, Synop. Vert. Anim. Tasm.: 38, 8. Munro, 1958, Handbk Aust. Fish.: 95, fig. 653 [instalment No. 23 in *Fisheries Newsletter*, xvii, 5, May, 1958: 19, fig. 653].

*Macroramphosus elevatus* Waite. McCulloch, 1929, *Mem. Aust. Mus.*, v, i: 83. Whitley and Allan, 1958, The Sea-Horse and its Relatives: 70, colored pl., fig. 5; text-fig. 21, No. 1.

*Macrorhamphosus scolopax* Linné. Mohr, 1937, Dana-Report No. 13: 36.

*Tasmanian status.*—The right of this species to appear in the Tasmanian list (from which it is omitted in the Handbook) has been discussed above.

*Two recent occurences.*—Two examples have recently passed through my hands: (*a*) *Ls* 99.8, *Lt* 118.6, caught 21st May, 1954, in 6-7 fathoms (Munro (1958:93) gives range as 23-84 fathoms) on gritty bottom in D'Entrecasteaux Channel, by Mr. M. Lynch and forwarded by Mr. E. Andrews, Senior Inspector of Fisheries; (*b*) *Ls* 75.8, *Lt* 88.2, from Bridport, Dorset, submitted for identification to the Queen Victoria Museum, Launceston, by Scottsdale High School, through Mr. J. R. Skemp.

As the following data (all values in this paragraph in *TLs;* smaller individual first) show, these two examples agree tolerably well in many of their proportions. Length to origin of: pectoral 479, 509; first dorsal 792, 715; second dorsal 918, 881; ventral 752, 731; anal 784, 799. Length of: eye 103, 95; snout 309, 327; head 501, 496. Length to vent (middle) 731, 769. In this, as in other species of the genus, however, striking variations in outline may be exhibited by individuals of different, and even by those of comparable, size; and in the present specimens (whose total lengths are in the ratio 1:1.34) some noticeable differences in relative depth are found: depth at back of head is in (*b*) greater than depth at vent (302, 290), in (*a*) less (282, 231): depth at front of eye is in (*b*) rather greater than at second dorsal origin dorsal origin (157, 153), in (*a*) less (141, 191). Associated with these variations in depth are differences of slope in various sections of the contour (especially behind the dorsal and/or anal fins) which may result in striking differences in the anteroposterior extension of the unpaired fin bases (though these bases, measured directly from first to last ray, are of closely comparable magnitude). Thus the base, between parallels, of first dorsal in the two individuals is 49, 85, of second dorsal 21, 43; the anal however exhibiting no significant difference (135, 131).

In *TLs*, length of second dorsal spine is 203 (*b*), 350 (*a*). Length of this spine in (*b*) is 2.7 in head [this is well outside range given by Munro (1958) 'from 1.8 in head to longer than head', though no injury is apparent], in (*a*) 1.3: in Johnston's Port Sorell specimen 1.2.

## Genus **NOTOPOGON** Regan, 1914

### *NOTOPOGON ENDEAVOURI* Mohr, 1937

(Text-fig. 2)

*Notopogon endeavouri* Mohr, 1937. Dana-Report No. 13: Revision der Centriscidae (Acanthopterygii Centrisciformes): 49, text-fig. 23.

[?] *Centriscops humerosus* Richardson. Waite, 1911, *Rec. Cant. Mus.*, 1, 3: 169 [*non* Richardson].

*Centriscops humerosus* Richardson. McCulloch, 1911 [*partim*], Zool. Res. Endeavour, I, i: 24 [*partim*] pl. v and fig. 9 [*non* Richardson].

*Notopogon lilliei* Regan, 1914 [*partim*], *Ann. Mag. Nat. Hist.* (8), xii: 18, 20.

*Notopogon lilliei* Regan. Regan, 1914, Brit. Antarct. *Terra Nova* Exped. 1910, Zool. I, 1: 15, pl. xvii, fig. 4. McCulloch, 1914, Biol. Res. Endeavour, II, 3: 91. Lord, 1923 [*partim?*], *Pap. Proc. Roy. Soc. Tasm.*, 1922: 64. Lord and Scott, 1924 [*partim?*], *Vert. Anim. Tasm.*: outline fig. on p. 38. Munro, 1958 [*partim*], Handbk Aust. Fish.: 95: text *partim*, but both the figs numbered 657 [instalment No. 23 in *Fisheries Newsletter*, xvii, 5, May, 1958: 19: text *partim*, but both the figs numbered 657].

*Notopogon endeavouri* Mohr: Whitley and Allan, 1958, The Sea-Horse and its Relatives: 21, fig. 73.

*Tasmanian example.*—A specimen, *Ls* 202.5, estimated *Lt* 232.5, preserved in deep freeze at the Fisheries Cannery, Bicheno, Glamorgan, and made available for description by Mr. F. J. White, Manager, has thawed out in good order and still most beautifully colored. This fish was caught near Bicheno in the course of ordinary commercial fishing.

*Fin counts, dimensions.*—Mr. White's specimen has D. vii, 14 (last cleft to base). A. 17 (last three set close together). V. 1, 5. P. 18. A series of dimensions, expressed in *TLs*, is set out in Table V.

*Comparison with figures of type and of McCulloch's specimens.*—No indication of the relative size of the figure of the cotype (Mohr, 1937, text-fig. 23) is provided: it is perhaps natural size or near to it, in which case it is reasonably comparable in size with our specimen, which is approximately one-third as long again. In general form the two fish are extremely similar, there being no significant difference (and in most cases surprisingly close correspondence) in proportional size (relative to length to caudal base) of eye, snout, head, length of dorsal spine, depth at various parts of body, and in relative length to origins and terminations of fins. The most obvious variations found in our example are: second dorsal base decidedly more convex, relatively shorter, measured obliquely (10.5%, *cf.* 14%); direct length of anal base somewhat less (15%, 19%); caudal peduncle somewhat upturned (probably partly, and perhaps wholly, a postmortem deformation), much more tapering, its least depth being barely 0.6 of, instead of subequal to, its length.

From McCulloch's smaller individual, *Lt* 70 (1911, text-fig. 9) the present example differs markedly in outline. It agrees, however, tolerably well with his larger individual, *Lt* 265 or 270 (1911, pl. v), the most notable divergences exhibited by the Bicheno fish being the following: snout longer, about in ratio 6:5; snout markedly upturned (as in type), its dorsal tip being about 1.0, instead of rather less than 0.2 of, vertical eye-diameter above anteroposterior axis of fish, as represented by a line through middle of eye and middle of caudal peduncle; eye larger, about 7:6; a caudad displacement of first dorsal, accompanied by decrease in slope of profile between nuchal bristles and dorsal origin, and bringing origin of second dorsal spine slightly behind level of the anterior one-fifth of horizontal extent of anal base, instead of about vertically above anal origin; as a further consequence of this shift, termination of second dorsal base comes to lie absolutely (5 mm) about twice as far behind anal termination, thereby also increasing the excess in length of the ventral over the dorsal profile of the caudal peduncle (a divergence enhanced, in this specimen, perhaps fortuitously, by the upturned posture of the peduncle).

*General description.*—In rehandling part of his 1911 material, and in referring it to *Notopogon lilliei*, McCulloch gave a full general description of the two individuals he had figured earlier: and this would appear to be still the most detailed account given of Australian specimens. Examination of Mr. White's fish provides some additional data. Except perhaps in the case of length of caudal in head (fin imperfect; longest ray 3.1 in head) values for all ratios recorded by McCulloch fall within his (distinctly wide) range. Posterior nostril the larger, about twice as far from orbit as from enterior nostril. First dorsal spine not, second considerably, remainder greatly, compressed. Most pectoral rays are split longitudinally, for most or all of their length, into external and internal moities: a similar condition obtains in four of the five surviving caudal rays, their bases being in the upper part of the fin quite widely separated (presumably as result of postmortem injury), the disjunction being in the sagittal plane. Reference may be made to similar radial fission recorded in these Observations (1953: 161, 165) in *Brachionichthys hirsutus* (Lacépède), 1809.

Rays of second dorsal (and to a lesser extent rays of anal) are much flattened dorsoventrally, their right and left edges being each fringed, for at least its basal half, with a hard glossy denticulated or crenulated flange. Near middle of tuft, cephalic or nuchal bristles subcylindrical, proconcave, fairly sharply pointed, long (up to 3.5 mm); stouter, more obtuse posteriorly; more slender anteriorly: the patch merging at either end into the blunt spinules and irregular elevations of the highly rugose dorsum. Immediately in advance of bristle-patch, dorsal profile is locally and briefly (for an eye-diameter or less) distinctly convex; the tuft itself being set, however, in a shallow concavity. Two ridges noted by McCulloch as lying near the (trenchant) midventral edge of the trunk, and extending backwards to end of ventrals, form here the side-walls of a trough, into which the furled fins are wholly and neatly received. The maximum

TABLE V

*Notopogon endeavouri* Mohr, 1937. Dimensions—expressed as thousandths of standard length (202.5 mm)—of a specimen from near Bicheno, Glamorgan, Tasmania. Measurements not otherwise specified are made between parallels.

| Dimension | *TLs* | | |
|---|---|---|---|
| Eye: horizontal diameter, vertical diameter. Interorbital | 78 | 77 | 48 |
| Snout length: parallels, direct. Depth at middle of length | 296 | 311 | 32 |
| Head length: parallels, direct. Postorbital length: direct | 454 | 459 | 79 |
| Bristle patch: length to origin; length, parallels, direct | 415 | 39 | 54 |
| Pectoral: length to origin; length of longest ray; direct length of base | 464 | 151 | 74 |
| First dorsal fin: length to origin; base, parallels, direct | 800 | 74 | 133 |
| First dorsal spine: direct length. Direct length of third dorsal spine: total, exposed beyond sheath | 12 | 94 | 20 |
| Second dorsal spine: length to origin; direct length, maximum width without membrane | 809 | 143 | 20 |
| Second dorsal fin: length to origin; base, parallels, direct | 874 | 40 | 105 |
| Ventral fin: length to origin; length of spine; length of longest ray | 664 | 13 | 40 |
| Anal fin: length to origin; base, parallels, direct | 780 | 109 | 151 |
| Length of longest caudal ray preserved | 148 | | |
| Posterior nostril direct to: base of first dorsal spine; termination of second dorsal fin; origin of ventral fin | 588 | 748 | 459 |
| At level of specified point: depth below axis joining middle of eye and middle of caudal peduncle base; height above this axis; total height: | | | |
| Anterior border of eye | 59 | 49 | 109 |
| Posterior border of eye | 143 | 96 | 239 |
| Opercular border | 178 | 168 | 346 |
| Termination of pectoral base | 207 | 222 | 430 |
| Origin of ventral | 220 | 254 | 474 |
| Middle of vent | 183 | 262 | 444 |
| Origin of anal | 175 | 264 | 440 |
| Base of second dorsal spine | 170 | 257 | 427 |
| Termination of anal | 54 | 133 | 188 |

thickness of the fish, which slightly exceeds diameter of eye, is found immediately behind upper one-third of posterior border of orbit. McCulloch notes that dorsal spines after the second are 'largely hidden in the skin only the tips projecting'. The fin membrane, the character of which Mohr cites as a diagnostic feature of her species, is, indeed, very stout, being rather of the nature of a sheath: it is completely covered with scales, and is in its basal half virtually opaque. The wide slip of membrane flanking the posterior border of long second dorsal spine is wholly covered with heavy irregular scales, thickly beset with small ridges, spinules, and rugosities. The true appearance of these heavy membranes associated with all dorsal spines save the minute first one cannot be gathered from McCulloch's plate. Anterior border of large dorsal spine, shown smooth by McCulloch, and serrate by Mohr, is in our specimen minutely and obscurely denticulate.

*Coloration.*—Though within its three-sentence compass informative, McCulloch's treatment of the coloration (which Mohr quotes) is of necessity over-condensed. Indeed, I know of no published account that conveys anything like an adequate idea of its brilliance and diversity: even on thawing out from deep freeze, Mr. White's specimen presented such a striking array of colors as to make it one of the most beautiful fish I have seen.

The most extensive areas of color were eight: (*a*) large opercular patch of lime green, partly outlined posteriorly in white; (*b*) breast, bounded by operculum, pectoral base, slightly proconvex white arc from pectoral base to pelvic, and ventral border, chiefly purplish brown, heavily and irregularly splashed with light-green, marked with ten white spots, and narrowly bordered ventrally by an internal arc of pale purple, and an external arc of dull orange bearing four brighter orange spots; (*c*) subrectangular area, wholly pale green, bordered anteriorly by (*b*), ventrally by margin of body between pelvic and first one-third of anal base, posteriorly and superiorly by (*d*) and (*f*), respectively; (*d*) large obliquely-set oval area of pale purplish with some silver, extending from above most of anal base almost to level of origin of second dorsal, ringed (anteriorly by continuous line, posteriorly by proconcave line of large spots) with pale purplish and whitish; (e) lying behind (d), paler purple, with three large whitish patches on caudal peduncle; (f) above pectoral, purplish, with four or five large scale-like markings, each with radiating light lines and silvery periphery; (g) lying in advance of (f) more or less yellowish with some areas orange, with two large oblique suoparallel white markings behind and above eye; (h) bordered below by (f), (d), (e), mostly greenish, with subhorizontal whitish vermicula-

tions, the whole upper edge, constituting the dorsal profile from nuchal bristles to first dorsal spine, with a sharply delimited border, of even width throughout, of clear pale green.

Snout pale greenish yellow, somewhat dusky dorsally, elongate subterminal whitish subelliptical marking. White lobe from anterosuperior border of eye; white streak below eye, extending anteriorly to level of anterior nostril. Pectoral rays silver. Pelvic pinkish basally, then lighter, tip shining white. Post-pelvic spines glassy, Anal rays whitish, slightly dusky distally; a pink patch across the middle of the first few rays. Dorsal spines (which are strongly compressed) whitish; parallel white lines run inwards from them, and there are conspicuous white patches at bases of two of them. Dorsal rays silver; a narrow grey inframarginal streak along fin base. Caudal rays whitish, partly dusky, with some orange.

## Family SYNGNATHIDAE

### Key to and Conspectus of Syngnathidae Recorded from Tasmania

The subjoined schema is something more than a mere formal key: it incorporates a considerable amount of hitherto unpublished data, and presents, within the limits of its pattern of specification, a synoptic view of available knowledge on the local representatives of the family. It supersedes an earlier key to Tasmanian and ad-Tasmanian species (Scott, 1939).

Seventeen species are here recognized as Tasmanian: (1) *Lissocompus caudalis* Waite and Hale, 1921; (2) *Urocampus carinirostris* Castelnau 1872; (3) *Leptoichthys fistularius* Kaup, 1853; (4) *Leptonotus semistriatus* Kaup, 1856; (5) *Histiogamphelus briggsii* McCulloch, 1914; (6) *Syngnathus tuckeri* Scott, 1942; (7) *Syngnathus mollisoni* Scott, 1955, (8) *Syngnathus curtirostris* Castelnau, 1872; (9) *Syngnathus phillipi* (Lucas), 1891; (10) *Solegnathus robustus* McCulloch, 1911; (11) *Solegnthus spinosissimus* (Günther), 1870; (12) *Solegnathus fasciatus* (Günther), 1880; (13) *Stigmatophora nigra* Kaup, 1853; (14) *Stigmatophora argus* (Richardson), 1840; (15) *Phyllopteryx taeniolatus taeniolatus* (Lacépède), 1804 [*Phyllopteryx foliatus* (Shaw), 1804 in Check-List (McCulloch, 1929: 95)]; (16) *Hippocampus abdominalis* Lesson, 1827; (17) *Hippocampus breviceps* Peters, 1870. Of these 17 species, no fewer than 10—(1), (2), (3), (6), (7), (8), (9), (10), (12), (15)—represent additions to the Tasmanian fauna as it appears in the Check-List: while two species—(1), (8)—are not credited to this State in the Handbook (Munro, 1958).

For each species there is provided, in the order and grouping here given, the eleven items noted in this paragraph. Total rings: subdorsal rings: brood rings. Dorsal rays. Eye in snout: snout in head: head in trunk: trunk in tail. Approximate maximum total length (mm). Character of rostral crest. Presence or absence of opercular keel. [Any additional data is enclosed in square brackets.]

Various systems of symbols for the longitudinal ridges have been devised: perhaps the simplest is that employed in the Handbook (Munro, 1958: 82) and adopted here. Of two capital letters, the first locates ridge on body or tail (T = trunk, C = caudal): the second letter is U, M, or L, denoting, respectively, upper, median, lower. A mixed one-, three-, and four-letter notation used by Herald (1953: 233) provides three additional points of specification. Duncker's (1915) formal schema, covering the empiric array of combinations of ridges, has been reproduced by, and is more readily available in Weber & De Beaufort (1922) and Whitley & Allan (1958).

The information supplied is classified by a two-letter code (in parentheses); the first letter being concerned with novelty (in a broad sense), the second with the area of reference over which the novelty extends. In the set of first letters, "a" is used in connexion with non-metrical data and signifies new; "b" marks an extension of the accepted metrical range (whether by excess or deficit being evident from the context); "c" calls attention to a refinement in accuracy; "d" denotes a correction. In the second set, "t" signifies all literature examined; "h", literature other than these studies; "m", the Handbook (Munro, 1958). Thus, for example, (at) means information (non-metrical) now first published; (bh), extends range beyond that noted outside these studies; (am), not noted in Handbook. Thus constituted as a two-letter symbol, the notation applies only to the immediately preceding entry: converted to a three letter symbol by the doubling of the second letter, its application extends backwards, over more than a single item, to the immediately preceding colon or period (whichever is encountered first).

1 { Body without longitudinal ridges, the angles scarcely defined. Dorsal fin short; on 3 body rings; base $\leq$ its height; rays $<$ 13. Tail $\geq$ 4.0 in trunk.
12 + 56 (bt)-60 : 1 + 2 [0.2-0.3 + 2.0 (ctt)] : 0.5 + 12.9 (at). 11-12 (bt). 2.0-2.5 (bt) : 2.7 (bt)-3.1 : 2.2 (bt)-2.6 (bt) : 4.1 (bt)-4.8. 110. Obtuse, elevated, terminating on interobital space [text-fig. 3a (ct)]. Absent. [Paired submental barbels (text-fig. 3b), dermal appendages on head and trunk and tail (text-fig. 3c), may be present (att).] [Folds of brood pouch in the form of tumid lips: fairly rigid, though, as far as can be determined, without special stiffening plates; closely approximated in midventral line; the interval between their outer borders about half total width of tail in vicinity.] .... .... .... .... .... .... .... .... .... .... *Lissocampus caudalis*

Body with longitudinal ridges, the angles well defined. Dorsal fin long, or moderately long; on $\geq$ 4 rings; base $>$ its height; rays (except in some specimens of *Urocampus carinirostris*) $>$ 13. Tail $<$ 4 in trunk .... .... .... .... .... 2

2
- TM double (*i.e.*, 4 longitudinal ridges on each flank). Fulfilling both these conditions: TU and CU continuous, TM and CL continuous. Dorsal fin: origin behind vent by > length of base. 8-9 [Lord & Scott, in error, 18] + 49 [Lord & Scott, 42: error?]-57: caudal 6th or 7th-caudal 10th or 11th [Munro employs formally ambiguous notation: (6-7) + (10-11)]: subcaudal 12-14. 1.3 (am): 3.0-3.3 (bm): 1.5-2.5 (bm): 3.3-3.7. 110. Strong, elevated, confluent with supraorbital ridges. Present. [Simple and/or branched dermal appendages on head and trunk and tail may be present] .... .... .... .... .... .... .... .... *Urocampus carinirostris*
- TM single (*i.e.*, 3 longitudinal ridges on each flank). Not fulfilling both these conditions: TU and CU continuous, TM and CL continuous. Dorsal fin: origin not behind vent by > length of base (origin at, or very shortly behind, or usually, in advance of, vent) .... 3

3
- TU and CU not continuous. Tail: not whiplike; rings < 55; caudal fin present or absent; prehensile or non-prehensile. Trunk: depth slightly or markedly > width .... .... .... .... 4
- TU and CU continuous. Tail: whiplike; rings > 55; caudal fin absent; non-prehensile .... .... 16

4
- TM ending free posteriorly. Tail: caudal fin present, non-prehensile .... .... .... .... .... .... .... 5
- TM not ending free posteriorly (continuous with CU or CL). Tail: caudal fin absent; prehensile 11

5
- Brood pouch on trunk. Trunk > tail in length. Rings: trunk > caudal in number in most specimens, if caudal > trunk never by > 4; last caudal > penultimate in length. Caudal fin > (about 2) distance from enterior border of eye to posterior border of operculum. 23 (bh)-28 + 20-27: 3-4 + 5-6: 19-23 + 0 (cmm). 34-38. 6.0 (bm)-7.5 (bh): 1.1 (bm)-1.4: 2.0-2.5: 0.8-0.9. 560. Rudimentary. Absent. [Brood pouch lacks protecting flaps.] .... .... *Leptoichthys fistularius*
- Brood pouch on tail. Trunk < tail in length. Rings: trunk < caudal in number by > 4 (by at least 10); last caudal ≦ penultimate in length. Caudal fin < (usually about half) distance from anterior border of eye to posterior border of operculum .... .... .... .... .... .... .... .... .... 6

6
- Trunk: depth ≧ 2 its width; length < 2 head. Dorsal rays ≧ 37. Marked sexual dimorphism; female with dorsal profile conspicuously elevated and with acute ventral ridge. 19-21 + 46 (bh)-50: 3-4.2 (ch) [*i.e.*, 5 (bh)] + 5.1 (ch) [*i.e.*, 6 (bh)]-7: caudal 1st- caudal 15th (cm). 4.3 (bh)-7.2 (bm): 1.6-1.8 (bh): 1.3-1.9 (bh): 1.9-3.0. 250. Obsolete, confluent with supraorbital ridges. Absent. [Brood folds lacking plates.] [Eggs about 55-60, in one row posteriorly, in 2-3 rows anteriorly, above each flap (ah).] [Depth of trunk 2.4-3.4 width in males, 2.4 (bh)-5.0 in females.]. Total length > 200 .... *Leptonotus semistriatus*
- Trunk: depth < 2 its width; length < 2 head. Dorsal rays < 37. No marked sexual dimorphism; female without conspicuously elevated dorsal profile and without acute ventral ridge. Total length < 200 .... .... .... .... 7

7
- Rostral crest greatly elevated; its least height < 2 in snout; middle of superior border (well) above level of top of eye. Caudal annuli > 39. 22 + 39; 5 + 2: presumably subcaudal .23. 2.5: 2.1: 4.6: 1.7. 235. Thin, greatly elevated, reaching to behind eye. Absent. .... .... .... .... *Histiogamphelus briggsii briggsi*
- Rostral crest not greatly elevated; its least height > 2 in snout; middle of superior border not above level of top of eye. Caudal annuli < 39 .... .... .... .... .... .... .... .... .... .... .... .... 8

8
- Number of subdorsal rings: trunk > (>4) caudal. Dorsal: length to origin of fin < 3 (about 2½) base of fin; rays ≧ 33. 22 (bh)-23 + 40 (bh)-43 (at): 9 (bt)-10 + 1.9 (ch)-3 (bt): caudal 1st-caudal 12th (cm). 33 (bt)-35. 3.1 (dm)-3.3 (am): 2.1 (cm): 1.9 (bh)-2.2 (bh) [Handbook, 3 (dm)]: 2.1 (bh)-2.3. 132 (bh). Prominent; free margin sinuous (lowest near middle; terminating at level of anterior nostril. Absent. [Dorsal base somewhat elevated—emendation (1960) of original description (1942) (dm).] [Brood pouch folds with 1-3 series of subcircular or polygonal depressions internally: no protective plates: eggs imbedded in jelly-like matrix, in 2 lateral, and in 1-2 mesial, rows; mostly in single layer, but in at least 2 layers mesially.] .... *Syngnathus tuckeri*
- Number of subdorsal rings: trunk < (≦½) caudal. Dorsal: length to origin of fin > 3 (about 3½-4½) base of fin; rays < 33 .... .... .... .... .... 9

9
- Subdorsal annuli > 9. Dorsal: length to origin of fin < 3.75 (about 3.6 base of fin; rays ≧ 27. 10 + 44: 2.8 + 7 [Handbook, 8 (dm)]: presumably subcaudal. 28 (am). 5.6: 1.7 [Handbook, 1.6 (dm)]: 2.7: 2.2. 163. No conspicuous crest. Absent .... .... .... .... .... .... .... .... .... .... *Syngnathus mollisoni*
- Subdorsal annuli < 9. Dorsal: length to origin of fin > 3.75 (about 4.0-4.8) base of fin; rays < 27 .... .... .... .... .... .... .... .... .... .... .... .... 10

10
- Operculum not keeled. Head > 2.5 (about 3.0-3.5) in trunk. Eye < 2.5 (about 2.1) in snout. Snout: > 2.25 (≧ 2.5) in head; depth at its middle < 3.5 in its length. 18-19 + 42 (bm)-44: 0-1 + 4-5: 0 +16 (cmm). 20 (bm)-24. 1.8-2.1 (bh) (amm): 2.5-2.7: 2.9 (bh)-3.5: 2.2-2.4. 164. Low. Absent .... .... .... .... .... .... *Syngnathus curtirostris*
- Operculum keeled. Head < 2.5 about 2.0) in trunk. Eye > 2.5 (about 3.0-3.5) in snout. Snout: < 2.25 (≦ 2.0) in head; depth at its middle > 3.5 in its length. 18-20 + 40 (bm)-48 (bm): 1-2 + 5-6: 0-1 + 15-18 (cmm). 22-28 (bm). 3.4 (am): 1.9: 2.0: 2.4. 130. Low crest extending on to interorbital space. Present .... .... .... .... .... .... .... .... .... .... *Syngnathus phillipi*

11
- TM continuous with CU. Distal tail rings (about 20) each with a pair of fleshy pads on ventral surface. Rings: subdorsal > 9, all caudal; trunk > 22 (≧ 25); total > 70 (≧ 74). Head > 1.75 (about 2) in trunk .... .... .... .... 12
- TM continuous with CL. Distal tail rings without fleshy pads. Rings: subdorsal < 9, not all caudal; trunk < 22 (≦ 18); total < 70 (≦ 60). Head < 1.75 (about 1.5) in trunk 14

Depth of snout $<$ 5.5 (about 5.0) in its length. Depth of tail immediately behind dorsal fin $<$ 3.5 (about 3.0) in base of fin. TM attains dorsal profile near, or behind, middle of tail.

26-27 + 48-53: caudal 1st or 2nd—caudal 10th or 11th (ctt) [original description (McCulloch, 1911) 'ten body rings']: subcaudal. 29.34. 3.9-4.1: 1.7-1.9. 2.4-2.7 (bmm): 0.9 (cm)-1.0 (dm). 364. No definite crest (am). Absent. [Each trunk scute with a flattened central spine, from which radiate lines of smaller, but well developed, spines.] [Eggs large, isolated, in open cells on tail generic character, applicable also to two species of bracket No. 13.]

.... .... . .. ... .... *Solegnathus robustus*

12

Depth of snout $>$ 5.5 (about 7.0) in its length. Depth of tail immediately behind dorsal fin $>$ 3.5 (about 4.0) in base of fin. TM normally (dh) attains, or virtually attains, dorsal profile immediately behind termination of dorsal fin [in an earlier key (1939) statement is given without qualification: I have since examined a specimen of *Solegnathus fasciatus* in which the condition does not obtain.] .... ... ... .... .. .... 13

Scutes convex, intensely spiny: at middle of either lateral border of each trunk scute a four-rayed or five-rayed cluser of spines, diverging from an enlarged central spine or small group of spines. Occipital scute a rosette, with one central, and six-eight peripheral, lobes. Two preanal rings orange.

27-29 + 51-55: caudal 1st-caudal 11th (bt) (ctt): subcaudal. 35-38. 4.0-5.4 (bt): 1.7: 2.0: 1.2 (am). 320. No definite crest (am). Absent. [Each trunk scute with a system of spinigerous ridges in the form of a lozenge, or ellipse; and a vertical ridge from apex to apex, terminating in a large two-crowned or three-crowned spine that forms part of longitudinal body ridge.] . .... .. .. .... *Solegnathus spinosissimus*

Scutes flattish, mainly rugose: at middle of either lateral border of each trunk scute a spinigerous fusiform fascia, with an enlarged central spine, or an elliptical boss with elevated centre, from which radiate numerous rows of blunt spinules. Occipital scute with three subequal lobes. Preanal rings blackish.

13

25-28 + 51 (bt)-56 (bt): caudal 1st or 2nd (bt)-caudal 10th or 12th (bt) (ctt): subcaudal. 36 (bt)-41. 4.0-5.0: 1.6 (bt)-1.7: 2.0: 1.1 (am). 420. No definite crest (am). Absent. [Each trunk scute with a system of about three to about six subvertical, rather sparsely, often obscurely, spinigerous ridges that through most of their length are subparallel, becoming approximated above and below, where they terminate in a large two-crowned or three-crowned spine that forms part of longitudinal body ridge.] *Solegnathus fasciatus*

Head: axis at an oblique angle to that of trunk; $<$ 2.0 ( about 1.5) snout. Rings: trunk $>$ 15 (about 17-18); caudal number $>$ 2.5 (about 4) trunk number; subdorsal, caudal number $>$ 2 trunk number; brood $>$ 12 (usually 17-19), none on trunk. Large unbranched foliaceous appendages (mostly paired on head, trunk, tail. Eggs unprotected.

17-19 (bt) + 32-37: 1-2 + 5-7: caudal 1st-caudal 17th, 18th or 19th (cm). 27-36. 6. 1 (bt)-10.0 (bt): 1.4-1.6 (bt): 1.5 (bt)-1.8 (bt): 1.1 (bt)-1.3 (bt). 460. Snout compressed and, specially at middle of length, somewhat elevated, but no separate crest developed: a pair of superolateral spines in proximal one-third (cm). Absent. [Depth of body 1.8 width in young females, 2.9 (bt)-4.2 (bt) in adult females, less in adult males.] [Enlarged spines comprise: one on head, one on neck, pair on back behind middle of trunk, pair near middle of breast, 4-5 (bm) sets on dorsal surface of tail, all, or some (dm), paired (usually at least first two sets paired)—all these normally bear appendages: also, lacking appendages, one pair flanking dorsal fin near its origin, one pair on ventral profile just in advance of vent (amm).] ...

14

.... .... .... .... *Phyllopteryx taeniolatus taeniolatus*

Head. axis about at right angles to that of trunk; $>$ 2.0 (about 2.5-3.0) snout. Rings: trunk $<$ 15 ($\leq$13); caudal number $<$ 2.5 (about 2) trunk number; subdorsal, caudal number $<$ 2 ($\leq$ 1) trunk number; brood $<$ 12 (usually 5-8), commonly one or more on trunk. Smallish, simple or branched, slender, tapering appendages (characteristically unpaired) may occur on head and trunk, not on tail. Eggs enclosed in a permanent sacklike brood pouch .. 15

Subdorsal rings $\geq$ 6; of which $\geq$ 3 are subcaudal. Dorsal: rays $>$ 24; base $>$ 1.5 (about 2) postorbital head. Head $<$ 2.75 snout. Total length $>$ 150.

11-13 + 42 (bt)-49: 2.3 (ct)-5.0 + 2.0 (bt)-5.0: 0-1 + 5.7 (cmm). 26-31. 1.9 (bt)-3.4 (bt): 2.0 (bt)-2.5: 1.1 (bt)-1.8 (bt): 2.2 (bt)-3.3 (bt). 260. Short high crest on proximal portion of snout. Absent.

15

.... .... .... .... .... .... .... *Hippocampus abdominalis*

Subdorsal rings $<$ 6; of which $<$ 3 (usually 1) are subcaudal. Dorsal rays: $<$ 24; base $<$ 1.5 postorbital head. Head $>$ 2.75 snout. Total length $<$ 150 (seldom $>$ 75).

11 + 38-42: 3-4 + 1: 1-2 + 3-4 (cmm). 19-22. 2.1: 3.0: 1.5: 1.8-1.9 (bm). 75. Proximally, snout is sharply elevated, rising to, or beyond, eye-level. Absent.

.... .... .... .... .... .... .....*Hippocampus breviceps*

TM: does not extend beyond 1st caudal ring; in female produced to form a sharp edge. Opercular keel well developed in young and adult. Subdorsal annuli: trunk number $>$ caudal number. Total length $<$ 180 (normally $\leq$ 110).

16-19 (bt) + 58-72: 10-13 (bt) + 6-7: 0 + 14 (cmm). 35-43. 5.0-6.8 (bm): 1.5 (bt)-1.7: 1.6: 1.6-2.3 (bt). 108. Low, terminating in advance of eye. Present in all stages. [In males, trunk slightly wider than deep; in females, more than twice—*e.g.*, 2.2 (ct).] [TM ends free on last trunk ring (bt) or 1st caudal ring.] [Eggs large, isolated, in cutaneous cells, enclosed in a completely closed brood pouch formed by paired cutaneous folds—generic character, applicable also to next species.]

16

.... .... .... .... .... .... .... .... *Stigmatophora nigra*

TM: extends beyond 1st caudal ring; in female not

produced to form a sharp edge. Opercular keel feebly developed in young, usually absent in adult. Subdorsal annuli: trunk number ≤ caudal number. Total length > 180. 17-22 + 68-90: 7-10 + 8-12: 0-1 + 16-20 (cmm). 43.58 (bh). 6.0 (bt)-9.3 (bt) 1.4 (bt)-1.6 (bt): 1.3-1.7 (bt): 1.7-2.8. 281 (bt). Low, terminating in advance of eye. Feeble in young; generally absent in adult, but (dh) see Scott (1960:90)—other examples with keel since examined. [TM ends on 6th-24th (bt) caudal ring: Australian authors customarily state 6th; Weber & de Beaufort (1922: 98) give 10th-14th; in 6 Tasmanian individuals the ridge terminates on 6th, 7th, 15th, 17th, 21st, 24th caudal ring.] .... .... .... .... .... .... .... .... .... *Stigmatopora argus*

## Genus **LISSOCAMPUS** Waite and Hale, 1921

### *LISSOCAMPUS CAUDALIS* Waite and Hale, 1921

(Text-fig. 3)

*Lissocampus caudalis* Waite and Hale, 1921, *Rec. S. Aust. Mus.*, 1, 4: 306, fig. 46. Type locality: Kangaroo Island, South Australia.

*Lissocampus caudalis* Waite. McCulloch, 1929, *Mem. Aust. Mus.*, v, i: 91. Munro, 1958, Handbk Aust. Fish.: 88, fig. 611 [instalment No. 21 in *Fisheries Newsletter*, xvii, 3, March, 1958: 20, fig. 611].

*Tasmanian record.*—This species has been reported only from South Australia and Victoria. Three specimens, (*a*), (*b*), (*c*), total length 100.5, 91, 68, standard length 98.5, 88.9, 66.6, respectively, collected on Fisher Island, Bass Strait by Mr. C. B. Mollison add it to the Tasmanian list. The largest individual is a male. Mr. Mollison observes, *in litt.*, 22nd September, 1959, 'the pipefish are to be found commonly in fine kelp attached to granite slabs on the eastern side of South Point (Fisher Is.). I obtained them by cutting kelp near the holdfasts and shaking it out on the rocks, when two or three specimens were noticed among molluscs and crustaceans. In life they are very similar to the stems of the kelp; mottled grey-violet on brown; markings seem very irregular and vary for each individual, but you may find a pattern'. Mr. Mollison has since informed me that searches made at this site on two subsequent visits by C.S.I.R.O. parties have failed to secure further examples. No direct statement is made by Waite & Hale of the depth at which the type material was collected, but a probable inference is that was obtained, like the present material, at a shallow depth. Herald (1953: 231) has pointed out that pipefishes taken in the Marshall and Marianas Islands in Operation Crossroads in 1946 seemed to be clearly divisible into intertidal and deepwater forms, with a demarcation line between the two habitats at a depth of about 10-15 ft. Little systematic attention has been given to this matter in the study of Australian syngnathids (of the two species described by the writer the unique holotype of one, *Syngnathus mollisoni*, was collected at a probable depth of 25 fathoms, while the several known specimens of the other, *Syngnathus tuckeri*, are of shallow water origin: most local species probably occur normally at no great depth).

*Supplements to original description.*—Available data on the characters of this form, as summarized by Munro (1958), appears to be confined to that afforded by the original description of the holotype female, 97 in length, collected at Kangaroo Island in 1901 (Waite & Hale note they had before them a second female, 102 long, from the same locality). The present material provides some interesting supplementary information—points of special significance are the presence in some individuals of two curious barbels and other dermal appendages, and the nature of the brood pouch.

*Meristic and other metrical data.*—Values for the three Fisher Island examples are in descending order of total length (corresponding values for holotype, where available, in parentheses). D. 12, 11, 11, (11). P. 6, 5, 5, (5?). C. 5, 5, 5, (10) (I do not find more than 5 caudal rays: Waite & Hale's entry 10 may possibly represent a count of halves of divided rays). Rings 12 + 58, 12 + 57, 12 + 56 (12 + 60). Subdorsal rings 0.2 + 2.0, 0.3 + 2.0, 0.3 + 2.0 (1-2: 'the dorsal commences on the posterior edge of the last body ring'). Brood rings 0.5 + 12.9 (*i.e.*, pouch begins on last body ring), —, —, (—). Eye in snout 2.1, 2.2, 2.5 (2.0); in head 6.3, 6.8, 6.8, (6.2). Snout in head 3.0, 3.1, 2.7, (3.1). Head in trunk 2.6, 2.6, 2.2, (2.5); in total length 16.0, 14.4, 13.3, (15.5). Trunk in tail 4.6, 4.1, 4.5, (4.8). Tail in total length, 1.3, 1.4, 1.4, (1.3). As *TLt* (Tasmanian specimens only): trunk 165, 180, 163; length to dorsal origin 222, 241, 232; dorsal base 28, 29, 29; length of pectoral 19, 20, 21; length of caudal 19, 23, 21, length of brood pouch 259, —, —. In largest local individual depth (in parentheses width) (*TLt*) at: middle of eye 19 (18), end of operculum 28 (20), vent 29 (19), end of pouch 20 (19); maximum (near middle of trunk) 30, 19. (It should be noted that in proportions given as *TLt* the last digit—though it is convenient formally to record it— is commonly suspect—dimensions having been measured only to nearest tenth of a millimetre).

*Dermal appendages.*—These are present in our three examples (text-fig. 3c). No mention of them is made in the original account of *L. caudalis*; nor have they been reported for the only other member of the genus, *L. affinis* Whitley, 1944, from Western Australia. Omission of notice of them in the description of the type material may be due (*a*) to oversight (they are scarcely observable without a lens); (*b*) to their loss by injury (*e.g.* postmortem abrasion); or (*c*) to their failure to develop in those specimens. With regard to (*c*), it is to be observed that the presence of such appendages in some individuals and their absence in others has been reported as a normal state of affairs in some pipefishes— *e.g.*, *Urocampus carinirostris* Castelnau, 1872, and (Herald, 1953: 260) *Micrognathus brevirostris* (Rüppell), 1840 [contrast, however, Munro (1958: 87), who notes, simply, 'cutaneous appendages on head nape and body ridges'.] Disposition and degree of development show individual variation—most conspicuous in specimen (*a*), least

in (*b*): there may be differences between two sides of the fish. In one or more cases the following may be observed. On head: 1 median preorbital, at end of rostral ridge, minute, simple; an incomplete ring of up to at least 8 (2 or 3 above and below most noticeable) on periphery of eye; on frontal region 3 small, unbranched (*a*), or 1 moderate-sized, branched (*c*). On trunk: along midlateral line 1 of fair size on each ring, mostly simple, if branched seldom with more than 2 branches; along line of junction of the flattish flank and the rounded belly (which latter lacks appendages) runs a line of pores, every third or fourth of which may bear a smallish simple appendage; on dorsal surface (in all individuals) 5 pairs, largish, branched (sometimes complexly)—proceeding caudal, the anteroposterior intervals between pairs decrease, the first three slightly, the last markedly. On tail: up to half a dozen pairs, small, simple, on dorsum of about every third or fourth ring.

*Barbels.*—Arising from ventral surface of snout, at a distance of rather more than their own length from free tip of lower jaw, is a pair of processes. In specimen (*a*) (text-fig. 3*b*1) they are subcylindrical (right slightly dilated distally) and unbranched; directed downwards and backwards at such an angle as to continue the general oblique profile of lower half of anterior wall of rostrum bounding the subvertical mouth-cleft; slightly divergent, their tips about one-fifth as far again apart as their bases, the interval between which is subequal to length of process, itself equal to diameter of eye (1 mm): general color pale horn, with some basal clouding, and with a minute but distinct subterminal ring, of red-brown. As developed in this individual, they present a novel appearance, the overall appearance of the anterior portion of the head coming to be quite unreminiscent of that in any pipefish with which I am acquainted. In (*c*) (text-fig. 3*b*3) they are non-rigid multifid, as preserved, not erected, the whole structure collapsed flat against rostrum: general color pale brown, ashen at insertion. In this form the structures clearly present themselves simply as large cutaneous appendages not essentially different from, though larger than, those developed elsewhere— thus they are here, as in the largest fish considered alone they certainly are not, readily assimilable to the cephalic dermal fringes of *e.g.*, certain species of *Ichthyocampus* and perhaps also to the subrostral tags sometimes found—see figure by McCoy (1882, pl.65); contrast figure by Waite and Hale (1921): for remarks, with figure, see Scott (1934)— in *Phyllopteryx taeniolatus taeniolatus* Lacépède (dealt with in the three sources just cited under the name of *P. foliatus* (Shaw), 1804). In (*b*) all that is observable (text-fig 3*b*2) is a pair of very small blackish conical papillae: this reduced condition may conceivably be due to injury but there is no direct evidence that such is the case.

*Brood pouch.*—The brood pouch, not previously known, proves to be extensive, involving 0.5 + 12.9 rings; the most anterior thus being that carrying the vent (in *L. affinis* Whitley, 1943, from Western Australia, the brood pouch is noticed as being 'below the first ten tail rings'). In our specimen a narrow midventral slit runs the full length of the organ, and for the greater part of its length it is bounded by a pair of tumid lips, each about one fourth as wide as the whole ventral surface, and slightly wider than its own height. Posteriorly, these elevations lapse to virtual extinction near the end of the 12th tail ring, the slit for the rest of its length (about one ring) expanding very slightly, and being now bordered by small thin fleshy blackish fringes: anteriorly, the ridges, though declining steadily in height cephalad over about two rings, do not appear to suffer so great or so abrupt a lapse as they do posteriorly, but again the terminal portion of the slit, in this case throughout its appearance on hinder half of anal ring, is bordered with thin fleshy fringes. Several small folds developed at the extreme anterior end of the slit appear to be continuous with a more complex system of plicae flanking the vent, and the association of the external structure of the brood pouch with the external structure of the anal region is notably close. Though the whole structure is tolerably rigid, no plates have been observed in the folds.

## Genus SYNGNATHUS Linné, 1758

### *SYNGNATHUS CURTIROSTRIS* Castelnau, 1872

*Syngnathus curtirostris* Castelnau, 1872, Proc. Zool. *Acclim. Soc. Vict.*, 1: 243. Type locality: St. Vincent's Gulf, South Australia.

*Syngnathus curtirostris* Castelnau. McCulloch, 1929, *Mem. Aust. Mus.*, v, i: 86. Scott, 1953, *Pap. Proc. Roy. Soc. Tasm.*, 1952: 150. Munro, 1958, Handbk Aust. Fish.: 82, fig. 569, p. 83 [instalment No. 20 in *Fisheries Newsletter*, xvii, 2, February, 1958: 18, fig. 569, p. 19].

*Pugnaso curtirostris* (Castelnau). Whitley, 1948, *Rec. Rust. Mus.*, xxii, 1: 75.

*Tasmanian status.*—It seems expedient to call attention to the non-inclusion of Tasmania among the States (South Australia, Victoria) given for this species in the Handbook. Earlier the Check-list gave South Australia only: though included in Johnston's second list (1891), it was not accepted as Tasmanian by Lord (1923) or by Lord & Scott (1924). A specimen collected by Miss Ann Mather at Low Head, Dorset, on 21st February 1952, and recorded in these Observations (1953: 150), satisfactorily establishes this pipefish as a member of our fauna.

## Family MUGILIDAE

Three Tasmanian species: (*a*) *Mugil cephalus* Linné, 1758; (*b*) *Myxus elongatus* Günther, 1861; (*c*) *Aldrichetta forsteri* (Valenciennes), 1836: (*a*), (*b*) occur in all States, (*c*) in all States except Queensland. All of commercial importance—especially (*a*); though in Tasmania the abundance of the less-esteemed (*c*) gives it considerable significance.

KEY TO MUGULIDAE RECORDED FROM TASMANIA

Prominent adipose eyelid covering eye except for slit above pupil. Anal: originating below origin of second dorsal; its base ≐ base of that fin. Pectoral with axillary scale. Teeth: restricted to jaws; in each jaw a single row, setiform .... .... .... .... .... .... .... *Mugil cephalus*

No such adipose eyelid. Anal: originating in advance of origin of second dorsal; its base > base of that fin. Pectoral without axillary scale. Teeth: not restricted to jaws (occurring at least on vomer and palatines); in each jaw not in a single row, not setiform .... .... 2

2 Lateral line 43-46; predorsal 28. Scales: ctenoid; on cheek in 5 rows. Teeth: none on pterygoids, tongue, pharynx: in jaw in single row, close-set small incisors. Fins with white margins .... .... .... .... .... .... .... .... .... *Myxus elongatus*

Lateral line 54-58; predorsal 30-31. Scales: cycloid; on cheek in 2-3 rows. Teeth: on pterygoids, tongue, pharynx; in jaw in band, strong. Fins with brown margins .... .... .... .... *Aldrichetta forsteri*

## Genus **ALDRICHETTA** Whitley, 1945

*ALDRICHETTA FORSTERI* (Valenciennes), 1836

*Mugil forsteri* Valenciennes, 1836, Hist. Nat. Poiss. xi: 141—*ex Mugil albula* Forster MS. Type locality: New Zealand.

*Agonostomus forsteri* (Cuvier and Valenciennes). McCulloch, 1929, *Mem. Aust. Mus.*, v, 1: 118.

*Aldrichetta forsteri* Valenciennes. Munro, 1958, Handbk Aust. Fish.: 106, fig. 721 [instalment No. 26 in *Fisheries Newsletter*, xvii, 8, August, 1958: 18, fig. 721].

*Sample with two size classes.*—Towards the end of the year the young swarm round the coasts and enter brackish and fresh water in great numbers. The composition of a small sample secured during the course of night seine-netting carried out by holiday makers on the beach at Ulverstone, Devon, on 5th January, 1958 is of interest—two clearly defined size classes being present. Class A comprises six individuals, *Ls* 130.0, 128. 0, 120.5, 118.0, 114.5, 104.5 (mean 119.3 ± 3.5): class B, 8, *Ls* 67.3, 67.0, 63.5, 63.3, 62.5, 62.0, 59.0 (mean 63.8 ± 0.9). Class B is the more compact (V = 4.1 ± 1.0; *cf.* 7.1 ± 2.1). The groups are clearly independent—a test for the significance of the difference of the means gives $t = 6.43$.

*Proportions.*—Values given for each ratio are the range (in parenthes, mean) for class A; followed by the corresponding data for class B: (*a*) length to vent in *Lt* 1.9 — 2.1 (2.0), 1.9 — 2.0 (1.9); (*b*) depth in *Lt* 5.1 — 5.6 (5.4), 5.3 — 6.2 (5.7); (*c*) head in *Lt* 4.5 — 5.0 (4.7), 4.5 — 5.1 (4.7); (*d*) eye, not inclusive of adipose lid, in head 4.2 — 4.8 (4.4), 3.3 — 4.3 (3.9); (*e*) eye, inclusive of adipose lid, in head 2.9 — 3.7 (3.3), 2.6 — 3.2 (2.8); (*f*) interorbital in head 2.8 — 3.5 (3.2), 2.9 — 3.6 (3.3); (*g*) snout in head 3.5 — 4.0 (3.7), 3.3 — 4.2 (3.8). Among items (*b*), (*c*), (*f*), (*g*) as given in the Handbook (for adults?) limits are transgressed by the present data in two cases, namely, the (numerical) maximum for (*c*) and for (*f*). While with such small samples any such deductions must be drawn with extreme caution, it seems not improbable that real difference may exist between the two size classes in respect of ratios (*b*), (*d*), (*e*).

*Contrast with sample of Arripis trutta.*—The bimodal distribution of this sample of yellow-eye mullet contrasts trenchantly with the unimodal distribution of a sample of 50 individuals of young Australian salmon, *Arripis trutta* Bloch and Schneider, 1801, secured at the same time. Specifications of *Ls* of this sample are: range 61.5 — 96.5, $\bar{x}$ 77.4 ± 1.1, σ 7.6 ± 0.8, V 13.8 ± 1.4, range /σ 4.61, percentage of entries within $\bar{x}$ ± σ 74. The subspecies represented—see Fairbridge (1950) Malcolm (1959)—was not determined.

*Other species secured.*—Other species caught in these operations, three successive hauls on the one night, included the dusky sea garfish, *Hemirhamphus melanochir* Valenciennes, 1846 (three specimens examined, two females, *Ls* 364, 373, 1 male, 250) and one or more undetermined species of flounder.

### Family SIPHONOGNATHIDAE

Two Australian species, both referred to *Siphonognathus* Richardson, 1858, appear in the Check List: (*a*) *S. argyrophanes* Richardson, 1858, Western Australia (type locality, King George's Sound) South Australia, Victoria; (*b*) *S.beddomei* (Johnston), 1885 (type locality, Derwent River) Tasmania.

Of (*b*) Lord & Scott observe, 'We have been unable to trace Johnston's type, which was apparently not preserved, nor have we been able to secure further specimens'. A sketch found among Johnston's notes has been published by Whitley (1929, pl. IV, fig. 6). Whitley records that it was after an examination of Johnston's sketch that McCulloch recognized the fact that Johnston's fish was a *Siphonognathus*.

Species (*a*) is here for the first time recorded from Tasmanian waters.

KEY TO SIPHONOGNATHIDAE RECORDED FROM TASMANIA

A. Rays: first dorsal < 22 (≐20); second dorsal < 16 (≐ 12). L. lat. < 50 (≐ 40). Snout < 2 (≐ 1½) postorbital head. Barbel absent. Total length < 15 (≐ 10) maximum depth. Known length 120 mm .... .... .... .... .... .... .... *S. beddomei*

AA. Rays: first dorsal > 22 (≐ 24); second dorsal > 16 (≐ 21-22). L. lat. > 50 (≐ 105). Snout > 2 (≐ 2½) postorbital head. Barbel present. Total length > 15 (≐18-20) maximum depth. Length to 400 mm or more .... .... .... *S. argyrophanes*

## Genus **SIPHONOGNATHUS** Richardson

### *SIPHONOGNATHUS ARGYROPHANES* Richardson, 1858.

*Siphonognathus argyrophanes* Richardson, 1858, *Proc. Zool. Soc.*, 1857: 238, pl. vi. Type locality: King George's Sound, Western Australia.

*Siphonognathus argyrophanes* Richardson. McCulloch, 1929, *Mem. Aust. Mus.* v, ii; 325.

*First Tasmanian record.*—The first record for Tasmanian waters is provided by a specimen, standard length 324, total length 379.5, secured in a garfish net, in less than two fathoms of water, with a bottom of green seaweed, by Mr. Frank Henwood at Lady Barron, Flinders Island, in early August, 1957.

*Remarks.*—In Richardson's figure, which is reproduced by Waite (1921: 136, fig. 211), dorsal origin is shown as slightly in advance of pectoral origin: in our example dorsal origin is 4.5 mm caudad of pectoral origin. In the figure the anal appears to terminate beneath the 2nd or 3rd dorsal ray, counting cephalad; in our fish it ends below the 5th. Fin formulae usually given are, D. xxiv, 22; A. 14: the present counts are, D. xxiv, 21 (cleft to base); A 13—with P. 12 and C. 10 main rays.

*Principal proportions.*—These are here given in *TLs*. Head (hard, soft) 320, 333, snout 211, eye 28, interorbital 22, mouth cleft 63, tip of upper jaw to hind border of maxilla 90, barbel 28, caudal from hypural 171, caudal from ray-base 155, pectoral 62, longest pectoral ray 57, depth at front of eye 37, maximum depth (occurring at vent) 49. Length to: pectoral origin 327, dorsal origin 341, vent (middle) 727, anal origin 745.

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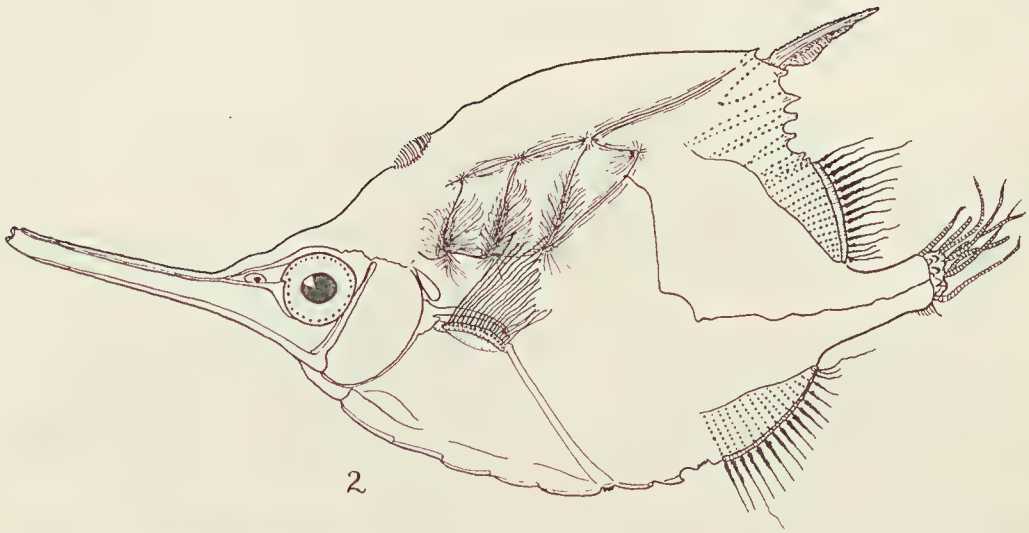

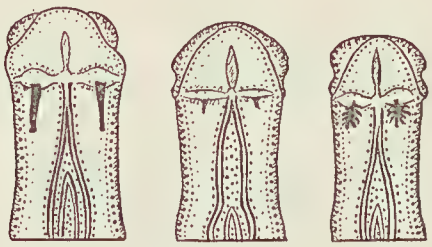

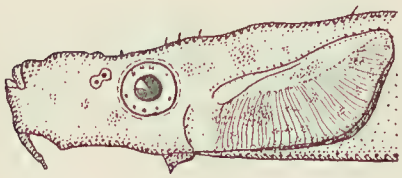


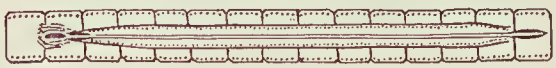


## LEGENDS TO FIGURES

FIG. 1.—*Parascyllium multimaculum* Scott, 1935. Ventral aspect of anterior half of head of a virtual topotype, 713.5 mm. in total length, from Green's Beach, Devon, Tasmania; × 1½.

FIG. 2.—*Notopogon endeavouri Mohr*, 1935. Outline sketch (scales, colour pattern not indicated) of a specimen, 202.5 mm. in standard length, from near Bicheno, Glamorgan, Tasmania (fins damaged; some caudal rays split sagitally): × 3/5.

FIG. 3.—*Lissocampus caudalis* Waite & Hale, 1921: all specimens from Fisher Island, Pass Strait. *a*.—Lateral aspect of head of a specimen 100.5 in total length: × 8. *b*.—Ventral aspect of head (*b*1, *b*2, *b*3, of specimens 100.5, 91, 68 mm., respectively, in standard length) to illustrate barbels (shown black): all × 14 1/3. *c*.—Dermal fringes, simple and compound, all approximately × 25. *d*.—Brood pouch of largest individual: × 1½.

# A CHECK LIST OF THE WRITINGS OF Dr. W. E. L. H. CROWTHER DEALING WITH THE HISTORY OF MEDICINE IN TASMANIA, NATURAL HISTORY, TASMANIAN ABORIGINES, &c., 1920 TO 1960.

*I—History of Medicine in Tasmania.*

1921. The Australian Army Medical Corps. *Tasmania's War Record*, 1914-1918. *Hobart, Walch.* pp. 169-179.

1927. Some Medical Aspects of the Settlement at the River Derwent (1803-1805). *Med. J. Aust.*, 1927, I, pp. 370-373.
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1941. The Changing Scene in Medicine: Van Diemen's Land, 1803-1853. *Med. J. Aust.*, 1941, II, pp. 29-34.
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1947. Mr. Jacob Mountgarret, R.N. The Pioneer Surgeon of Van Diemen's Land (1803-1828). *Med. J. Aust.*, 1947, I, p. 353.
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1927. Ectopic Pregnancy in Three Sisters. *Med. J. Aust.*, 1927, I, Apr. 23.

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*IV—Whaling, Sealing, &c.*

1920. Notes on Tasmanian Whaling. *Pap. Roy. Soc. Tasm.*, 1919, pp. 130-151.

1933. Voyage of the "Mary and Sally" to Macquarie Island for the Purpose of Obtaining Sea Elephant Oil and Seal Skins. *Pap. Roy. Soc. Tasm.*, 1932, pp. 39-46.

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*V—Tasmanian Aborigines.*

1921. *With Clive E. Lord.* A Descriptive Catalogue of the Osteological Specimens relating to the Tasmanian Aborigines contained in the Tasmanian Museum. *Pap. Roy. Soc. Tasm.*, 1920, pp. 137-152.

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1950. On the Formation and Disposal of a Collection. *Pap. Roy. Soc. Tasm.* 1949, pp. 83-92.

*VI—Bibliography.*

1956. Interlopers and Sojourners. *Biblionews.* 9, 1, pp. 1-2.

1956. Excursions into the Bibliography of Tasmania. The Bent Gazettes in the Tasmanian Archives. *Biblionews*, 9, 9, pp. 1-3.

1956. Excursions in Tasmanian Bibliography. A Further Excerpt. Andrew Bent: 1785 c.-1851. *Biblionews*, 9, 11, pp. 1-3.

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*VII—Obituaries.*

Obituary notices relating to the following doctors were published at appropriate dates in the *Medical Journal of Australia*:—

G. M. Anderson, H. Nairn Butler, W. I. Clark, Stuart C. Gibson, Eric Jeffrey, D. H. E. Lines, R. G. Scott, A. W. Shugg, G. Sprott.

In the *Papers and Proceedings of the Royal Society of Tasmania*, 1943: Dr. A. N. Lewis.

*Reference.*

GANDEVIA, Bryan: An Annotated Bibliography of the History of Medicine in Australia. Monograph No. 1 of the Federal Council of the British Medical Association in Australia. 1955.

W.E.L.H.C.

# PAPERS AND PROCEEDINGS

OF

# The Royal Society of Tasmania

## Volume 96

Edited by William Bryden

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1962.

# The Royal Society of Tasmania

Volume 96

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## LIST OF OFFICE BEARERS, 1961

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*Dr. D. Martin.
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# The Royal Society of Tasmania

## Papers and Proceedings Volume 96

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# Royal Society of Tasmania

*Annual Report for the Year* 1961.

### Annual Meeting.

The Annual General Meeting was held on Tuesday, 7th March, 1961, when the Annual Report and Statement of Accounts for the year 1960 were adopted by members. The following office-bearers were elected:—

*Vice-President*: Professor A. M. Clark.
*Honorary Secretary and Honorary Librarian*: Dr. W. Bryden.
*Honorary Treasurer*: Mr. G. E. A. Hale.
*Honorary Auditor*: Mr. A. M. Hewer.
*Council Members*: Mr. H. Allport and Mr. E. L. Carthew.

During the year Messrs. Carthew and Sharland left the State and their places on the Council were taken by Dr. D. Martin and Mr. E. C. Gifford respectively.

### Committees, &c.

Council made appointments as follows:—

*Standing Committee*: Mr. R. M. H. Garvie, Mr. W. F. Ellis, Dr. D. Martin, Dr. W. Bryden.
*Representatives on the Board of Trustees of the Tasmanian Museum and Art Gallery*: Mr. G. F. Davies and Dr. D. Martin.
*Representative on the Board of Trustees of the Botanical Garden*: Mr. R. S. McIntyre.
*Representative on the Nomenclature Board*: Mr. E. R. Pretyman.
*Representative on the Mount Field National Park Board*: Dr. J. M. Gilbert.
*Representative on the Library Association of Australia*: Dr. W. Bryden.

### Honorary Life Membership.

At a Special Meeting held during the year members agreed to change the Rules of the Society to make it possible, under certain set conditions, to elect members who have given outstanding service to the Society to Honorary Life Membership. Dr. J. Pearson, Dr. W. E. L. H. Crowther, and Mr. S. Angel were elected to Honorary Life Membership.

### General Meetings.

Meetings were held in each month, March to November, and the following lectures were given:—

*March*: "The Expanding Earth", by Professor S. Warren Carey.
*April*: "The Old Psychology", by Professor J. A. Cardno.
*May*: "Birds of the Tasmanian Midlands", by Mr. R. H. Green.
*June*: "Early Tasmanian Artists" (Part 1), by Mr. H. Allport.
*July*: "Norway's Mountains and Glaciers", by Mr. J. N. Jennings.
*August*: "Encyclopaedias of the Renaissance", by Mr. D. H. Borchardt.
*September*: "Radio Astronomy.", by Professor G. R. Ellis.
*October*: "Early Tasmanian Artists" (Part 2), by Mr. H. Allport.
*November*: "The History of Tasmanian Geology", by Mr. M. R. Banks.

### Royal Society of New Zealand.

One of the distinguished awards of the Royal Society of New Zealand is the Hector Memorial Medal and Award. This year it was presented to Professor H. Bloom who now occupies the Chair of Inorganic Chemistry in the University of Tasmania, but who was previously on the staff of Auckland University in New Zealand. On behalf of the Royal Society of New Zealand, His Excellency the Governor of Tasmania presented the medal and Award to Professor Bloom at the November meeting.

### Northern Branch.

The Northern Branch of the Society had another successful year. Council decided to publish the Wedge Papers edited by members of the Northern Branch and it is hoped these will be available early in 1962.

The Council of the Society held one meeting in Launceston in November.

### Additional Meetings.

Council decided to widen the scope of the Society in 1962 by holding a few specialist meetings in the late afternoon. These will be in addition to the ordinary general meetings and will be open to all members.

### Papers and Proceedings.

Volume 95 of the "Papers and Proceedings" was published during the year and once again exchange copies were sent to libraries in all parts of the world. Our library benefits very considerably from such exchanges, in fact, the bulk of our periodicals come to us in this way.

### Library.

Seven hundred and forty-two volumes were added to the library during the year, making a total of 33,400 volumes (periodicals and books). Council has been concerned at the lack of shelf space due to the increasing number of periodicals and has been considering ways and means whereby adequate space can be left for seating and also for the periodicals and books required by members. It does seem that a number of old and out-of-date textbooks could be removed and Council has asked a sub-committee to go into this matter and present a report on ways and means.

### Microfilming.

There are many documents in the library which are of great historical value. Council decided to approach the Government for a grant to have these unique and valuable documents microfilmed so that no matter what happens the text material will be preserved. Council is grateful to the Government for making funds available for this work on an annual basis and to the State Library for their co-operation.

### Equipment.

During the year a new film projector and new loud-speaker equipment were installed in the Society's room.

### Government Grant.

In addition to the Special Grant made by the Government for microfilming, the grants for the library and "Papers and Proceedings" have been continued.

### Thanks.

The thanks of the Society go out to all those who have assisted the activities of the Society during the year. To the Government of Tasmania, the State Library, the Tasmanian Muesum and Art Gallery, the University of Tasmania, the Office-Bearers, and Lecturers, and to all others who have assisted the Society during the year.

ROWALLAN, President.

## Northern Branch

*Annual Report*, 1961.

Following the Annual General Meeting in March, the Council of the Northern Branch of the Royal Society of Tasmania was composed as follows:—

*Chairman*: Dr. C. Craig.
*Vice-Chairman*: Mr. John Lord.
*Past-Chairman*: Mr. G. H. Stancombe.
*Honorary Secretary and Treasurer*: Mr. W. F. Ellis.
*Members of Council*: Mrs. B. J. Edwards, Mrs. I. J. Mead, Rev. C. O. Leigh Cook, Dr. J. C. H. Morris, Mr. T. W. W. Sharpe.

Dr. Craig and Mr. Ellis represented the Northern Branch on the General Council of the Society, and Mr. Ellis served as a member of the Standing Committee. Mr. Justice G. H. Crawford acted as the Branch's nominee on the Cradle Mountain-Lake St. Clair National Park Board.

### Membership.

The Branch membership at 31st December, 1961, was 235 persons. During the year, the following adjustments occurred:—

| | | |
|---|---|---|
| Elected | 25 | |
| Transferred to Branch | 2 | |
| | — | 27 |
| Resigned | 9 | |
| Removed | 2 | |
| Deceased | 3 | |
| | — | 14 |
| Net increase | | 13 |

### Activities.

Eleven General Meetings and one Special Meeting were held during the year, at which the following papers were presented:—

*General Meetings*:

24 *February*: "The Migration of Birds", by Mr. R. H. Green.
24 *March*: "Early Days in New Norfolk", by Mr. K. R. von Stieglitz, O.B.E.
21 *April*: "The Oral Literature and Tradition of Our Aborigines", by Mr. Roland Robinson.
26 *May*: "One Hundred and Fifty Years of Geologists and Geology in Tasmania", by Mr. M. R. Banks, B.Sc.
30 *June*: "Radio Astronomy at the University of Tasmania", by Professor G. R. A. Ellis, B.Sc., Ph.D.
4 *August*: "Some Aspects of the History of the Launceston General Hospital", by Dr. C. Craig, C.M.G., M.D., M.S., D.D.R.
25 *August*: "Veterinary Science in Afghanistan", by Mr. W. H. Stevens, B.V.Sc.
22 *September*: "Two Renaissance Encyclopaedias", by Mr. D. H. Borchardt, M.A., A.L.A.
27 *October*: "The Origins of the Legal Profession in England", by Professor N. C. H. Dunbar, LL.M., J.S.D.
16 *November*: "Some Little-known Tasmanian Animals", by Emeritus Professor V. V. Hickman, D.Sc., B.A., C.M.Z.S.
8 *December* (Members' Night):—
"Ikebana—Japanese Flower Arrangement", by Mr. K. R. von Stieglitz, O.B.E.
"An Expedition to Black Pyramid", by Mr. R. H. Green.
"The Life Cycle of a Wanderer Butterfly", by Mr. H. J. King.
"Some Tasmanian Churches and Their Windows", by Mr. J. Glennie.
"A Japanese Home", by Mrs. B. J. Edwards.
"Citizen of No Mean City", by Mr. T. E. Burns.

The average attendance at General Meetings during 1961 was 60.

*Special Meeting*:

A Special Meeting of the Branch was held on 9th March, 1961, at which the President, the Right Honourable the Lord Rowallan, presided. An address on "The Promise of Atomic Power" was given by Professor J. P. Baxter, C.M.G., O.B.E., B.Sc., Ph.D., F.A.A., F.R.A.C.I.

In addition, the Branch members attended a lecture arranged by the Australian College of General Practitioners (Tasmanian Faculty) at which Dr. John Hunt, D.M., F.R.C.P., spoke on "Family Life and Family Medicine in Russia".

### Excursions.

Five day excursions were held:—

9. *April*: York Town and Kelso.
7 *June*: Paton's and Baldwin's Mill.
13 *August*: Launceston Synagogue
24 *September*: Westbury District.
3 *December*: George Town.

In addition, an extended excursion to hydro-electric power installations on the Central Plateau was held during the long week-end on 4th-6th November. This was attended by 22 members and guests.

The Branch Council acknowledges, with appreciation, the facilities provided during the year at the Queen Victoria Museum by the Launceston City Council.

C. CRAIG, Chairman.
W. F. ELLIS, Secretary.

Papers and Proceedings of the Royal Society of Tasmania, Volume 96

# THE PERMIAN SYSTEM IN WESTERN TASMANIA

By

Maxwell R. Banks

*University of Tasmania*

and

N. Ahmad

*University of Aligarh*

(With 12 text figures.)

## ABSTRACT

Permian rocks occur at Mount Read, Mount Dundas, Mount Sedgwick, Zeehan, Firewood Siding, Strahan and Point Hibbs in Western Tasmania. The basal formation is exposed at Mount Read, Mount Sedgwick, Zeehan and Point Hibbs and consists of tillite. Striations on the basement at Mount Sedgwick indicate ice moving from the west. Sections up to and including the Golden Valley Group (Lower Artinskian) occur at Mount Sedgwick and Point Hibbs and a section from the Mersey Group up to and including the Cygnet Formation is found in the Firewood Siding Area near the mouth of the Henty River. The sections at Mount Sedgwick and Firewood Siding are much thinner than corresponding ones in north-western and south-eastern Tasmania but that at Point Hibbs is as thick as or thicker than corresponding sections.

## INTRODUCTION

The first record of Permian rocks in the area studied seems to be that of Montgomery (1891) who made brief reference to coal on the Henty River (see map, fig. 1). Johnston (1892) recorded some fossil plants from the Henty River area and correlated the coal measure there with the Mersey Coal Measures. In 1894 Dunn noted the tillite near Mount Read and commented on its similarity to the Dwyka of South Africa and to the conglomerates at Wild Duck Creek (Derrinal), Victoria. In the same year Moore noted the Permian fossiliferous and glacial beds on Mount Sedgwick and those at Zeehan (Zeehan Tillite) which he also described as Permian. The fluvio-glacial beds near Strahan were first described by Officer, Balfour and Hogg (1895). Several later workers dealt with the deposits mentioned above but no new work was added until Hills (1914) dealt with the Point Hibbs section. In 1925 Reid noted the probable presence of Permian rocks on Mount Dundas. Voisey (1938) included references to this area, particularly to the Point Hibbs and Malanna sections in his work on the Permian of Tasmania. Edwards (1941) noted the exhumed Permian surface on Mount Sedgwick and the Permian of

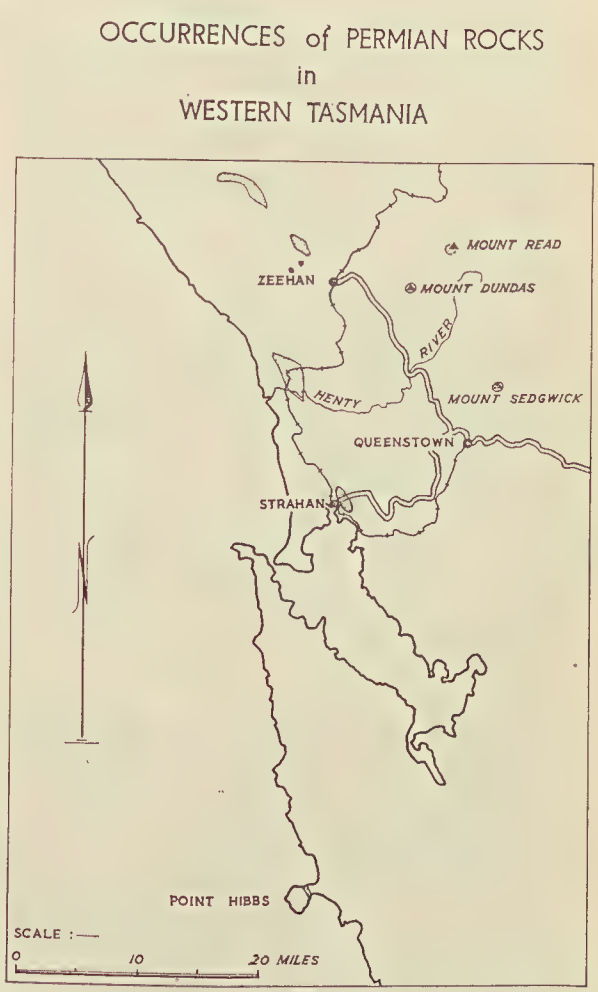



FIGURE 1

Mount Sedgwick was mentioned by Bradley (1954). Some of the Permian rocks at Firewood Siding, near Malanna, were described by Gill and Banks (1950). Campana *et al* (1958) and Spry (1958) re-established the Permian age of the Zeehan Tillite. Others have also commented on the Permian rocks considered in this paper but only as repetitions of earlier work.

Serious investigation of the Permian sections in this area began in November, 1953, when Professor K. G. Brill, Visiting Professor at the University of Tasmania, G. E. Hale and M. R. Banks spent a week measuring sections in the Malanna area. In January, 1957, the authors measured sections in the Malanna area, at Point Hibbs and on Mount Sedgwick and made observations on the Permian rocks on Mount Read and at Strahan. During the 1953 trip to Malanna sections were measured in railway cuttings and creek beds using a steel tape and abney level. The Mount Sedgwick section was measured by using a Brunton compass as a level and measuring cliff sections. The Point Hibbs section was measured by laying a steel tape along the dip of the vertical beds and reading off thicknesses directly until the fault zone was met and then by using the abney level. Thicknesses in the section in Geologists Creek, near Malanna, studied in 1957, were only estimates due to thick undergrowth.

During the work the authors were aided by the explicit directions on the route to Mount Sedgwick given by geologists of the Mount Lyell Company. This company also made available the services of Mr. Jock Gilfillan who was of considerable assistance. The Lyell-E.Z. Exploration Company made the work at Point Hibbs possible by making available to the authors one trip each way in a helicopter and later made aerial photographs available. The Electrolytic Zinc Company kindly allowed us to use their facilities and made Mr. John Druett available as a guide. The authors acknowledge with gratitude the assistance of these companies and their officers. The authors are also indebted to Mr. M. Longman, Geologist at the Tasmanian Museum for access to plant bearing shales from which Johnston had described fossil plants from the Henty River.

All bearings are related to true north.

## *MOUNT READ.*

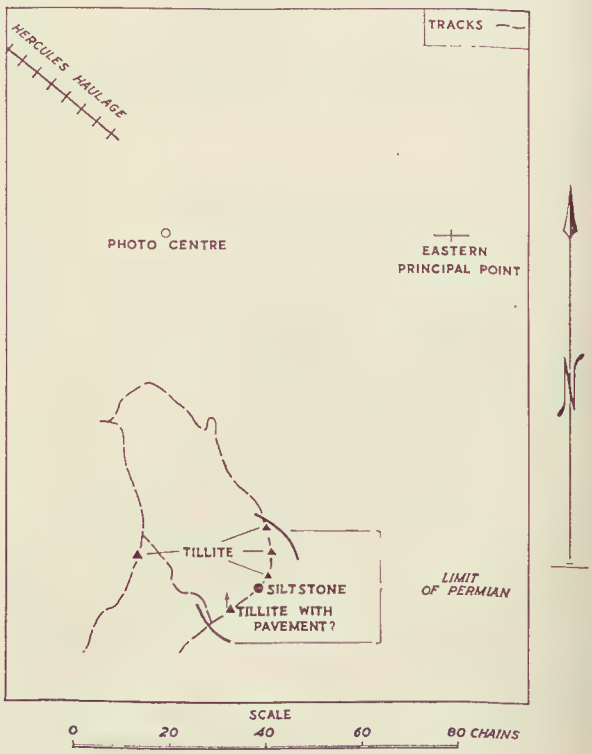
The earliest mention of Permian rocks near Mount Read is that of Dunn (1894) who mentioned a conglomerate with a great variety of pebbles on the south side of the track half way from Mount Read to Moore's Pimple. He remarked on its similarity to the Dwyka of South Africa and the conglomerate on Wild Duck Creek (Derrinal), Victoria, both considered as Permian. Hills (1915) gave further details. He considered that it was Permian as it contained fragments of undoubted "Silurian" rocks (now known to be Ordovician). Bradley (1954, p. 199) also mentioned this occurrence as showing that the Carboniferous peneplain in this area has an undulating surface with variations up to 80 feet in height.

A complete survey was not made by the present authors but two areas of Permian rocks were examined. On the track from Mount Read to Zeehan about half a mile south of the "L" Lode open cut on the south-west side of Mount Hamilton, tillite was found in a small depression (co-ordinates 8.5 cms. S.S.W. by S. of C.P., Zeehan 8, 23627) (see map, fig. 2).

The Permian rests on "sheared pyroclastics" of probable Cambrian age which have a steep easterly dip and the Permian has a horizontal fissility although no bedding could be seen. The rock is greenish grey. It is very poorly sorted with boulders up to 18 inches long in a fine-grained (clay and silt grade) matrix. The boulders are angular and sub-angular and are grey Owen Conglomerate, pink Owen Conglomerate, Eldon Group quartzites, green sandstone, black slate, quartz and rare feldspar porphyry. The rock is fairly well lithified. The tillite is probably not more than two feet thick and is a small remnant preserved in a hollow between hills of "sheared pyroclastics" which rise locally to more than 50 feet above the level of the Permian. There is no internal evidence in this exposure of a Permian age. The lithology and degree of lithification are very similar to known Permian tillites elsewhere in the State and quite dissimilar from those of the Pleistocene till in

SOME PERMIAN DEPOSITS

ON MOUNT READ




Based on air photo Zeehan Run 8 no. 23627

FIGURE 2

the West Coast area. The top of the plateau at Mount Read shows no sign of Pleistocene glaciation so that all available evidence from this outcrop suggests a Permian age.

The Permian age is confirmed by the other exposure of tillite and associated rocks. In a depression between hills of "sheared pyroclastics" about three-quarters of a mile south-west of "L" Lode Open Cut, tillite is found, resting on the pyroclastics (at point 10 cms. S.S.E. by S. of C.P. Zeehan 8, 23627) and in a runnel of an old track a surface of the pyroclastics shows a polished surface with striations trending 0° approximately. This may be part of the pavement beneath the Permian but this could not be established beyond doubt as the striations may be due to log hauling. Erratics in this vicinity reached a length of 33 inches and in addition to the types reported from the first locality include a black fine-grained quarzite. Otherwise the tillite at this second locality is very like that from the first. About 100 yards north-east along this track (at point with co-ordinates 9.7 cms. S.S.E. of C.P. Zeehan 8, 23627) olive-grey siltstones are exposed dipping at a moderate angle to the west off a small hillock of "sheared pyroclastics". These are well-sorted in that erratics are rare and small. They are poorly bedded. These siltstones contain articulated crinoid columns and attached cirri of a type common in the Permian System in Tasmania. The siltstones are overlain by tillitic material and similar siltstones occur, apparently above the tillitic material, further north along the track and are again overlain by tillitic material. On topographic grounds it seems probable that the section is basal tillite, siltstone with crinoids, tillite, siltstone, tillite, but in view of the poor exposure the succession cannot be regarded as established. The presence of the crinoid of Permian type established the age of the succession.

The surface of the plateau north and eact of these occurrences was not examined and there may be further outcrops. The two areas of Permian rocks found occupied small depressions in the surface of the "sheared pyroclastics" which rises perhaps as much as a hundred feet above the base of the Permian. To some extent the present topography on this part of Mount Read is a slightly subdued expression of the pre-Permian topography.

### *SECTION AT MOUNT DUNDAS.*

This section was not visited due to inaccessibility. Reid (1925) postulated that Permian sediments on the south-western fall of Mount Dundas on the evidence of fossiliferous boulders in some of the creek systems near Dundas. Elliston (1954, p. 172) stated that a thin layer of mudstone occurs between dolerite sills on Mount Dundas.

### *SECTION AT ZEEHAN.*

In 1894, Moore discovered the tillite north-west of Zeehan and considered it (1896a, p. 60) to be Permian in age on lithological grounds as also did Twelvetrees and Ward (1910). It has also been regarded as Precambrian (Hills and Carey, 1949; Carey, 1953), and Cambrian (Carey and Scott, 1952, p. 70; Elliston, 1954, p. 177) but Banks (1956, p. 193) regarded the age of the Zeehan Tillite as not then established. More recently Spry (1958) has suggested that the Zeehan Tillite is Permian on structural grounds and because it contains fragments of Dundas Group and Eldon Group rocks. He has also found a further occurrence of it north of the Pieman River and describes the rock from the different areas in some detail. The authors did not visit these areas. Campana and King (1958) give detailed evidence for a Permian age for the Zeehan Tillite.

### *SECTION AT MALANNA (MOUTH OF HENTY RIVER).*

The Permian rocks here were first noted by Montgomery (1891, p. 42) who gave the section as coal bearing beds overlain by sandstones and limestones with marine fossils and by white grit or sandstone. Johnston (1892) recorded *Glossopteris browniana, Gangamopteris spatula, G. obliqua* and *Noeggerathiopsis hislopi* associated with curious botryoidal concretions from the coal bearing beds and correlated them with the Mersey Coal Measures. Twelvetrees (1902a) noted that the impure limestones and mudstones overlie the coal measures. Twelvetrees (1902b, 1903) recorded details of two bores put down near Malanna in a search for coal and suggested (1902, p. lxxii) that the coal occurred on two horizons, one exposed near Malanna and the other below the limestone. Voisey (1938, p. 322) considered that only one formation containing coal was present, that above the beds with marine fossils. In this he was possibly influenced by the undoubted presence of coal bearing or carbonaceous beds above the marine beds in the railway sections. However, investigations by the authors suggest that there are two coal bearing formations separated by marine beds. The authors were unable to find any of the "curious botryoidal concretions" in the railway cuttings nor any *Noeggerathiopsis* and it is clear from Montgomery's statement (1891, p. 43) that the coal being investigated was on the flats just north of the Henty River, not as far north as the railway cutting. This has been checked in conversation with local residents. Specimens of the shale containing the plant fossils described by Johnston are in the Tasmanian Museum. The rock is a micaceous siltstone containing decomposed concretions probably of pyrite, now in the form of melanterite. It is thinly bedded with beds of dark-grey and medium-grey siltstone alternating from 0.1 inches to 0.25 inches thick. It is well lithified and shows some curved slickensided surfaces. No fossil seeds, nor sphenopsids, nor *Vertebraria* are present in the Museum specimens but large specimens of *Glossopteris* are present. One of the "botryoidal concretions" referred to by Johnston may be present but this is not certain. This material is much more lithified than any of the plant bearing siltstones seen in the railway cuttings and described later and the types of fossils are somewhat different in the two formations. The specimens in the Museum are characterised by extraordinarily large specimens of *Glossopteris* while specimens from the railway cutting contain numerous seeds, *Vertebraria* and sphenopsids. On the grounds of difference in degree of lithification and in the overall aspect of the plant assemblages it is considered that John-

## MAP OF HENTY RIVER (MALANNA) AREA SHOWING PERMIAN LOCALITIES

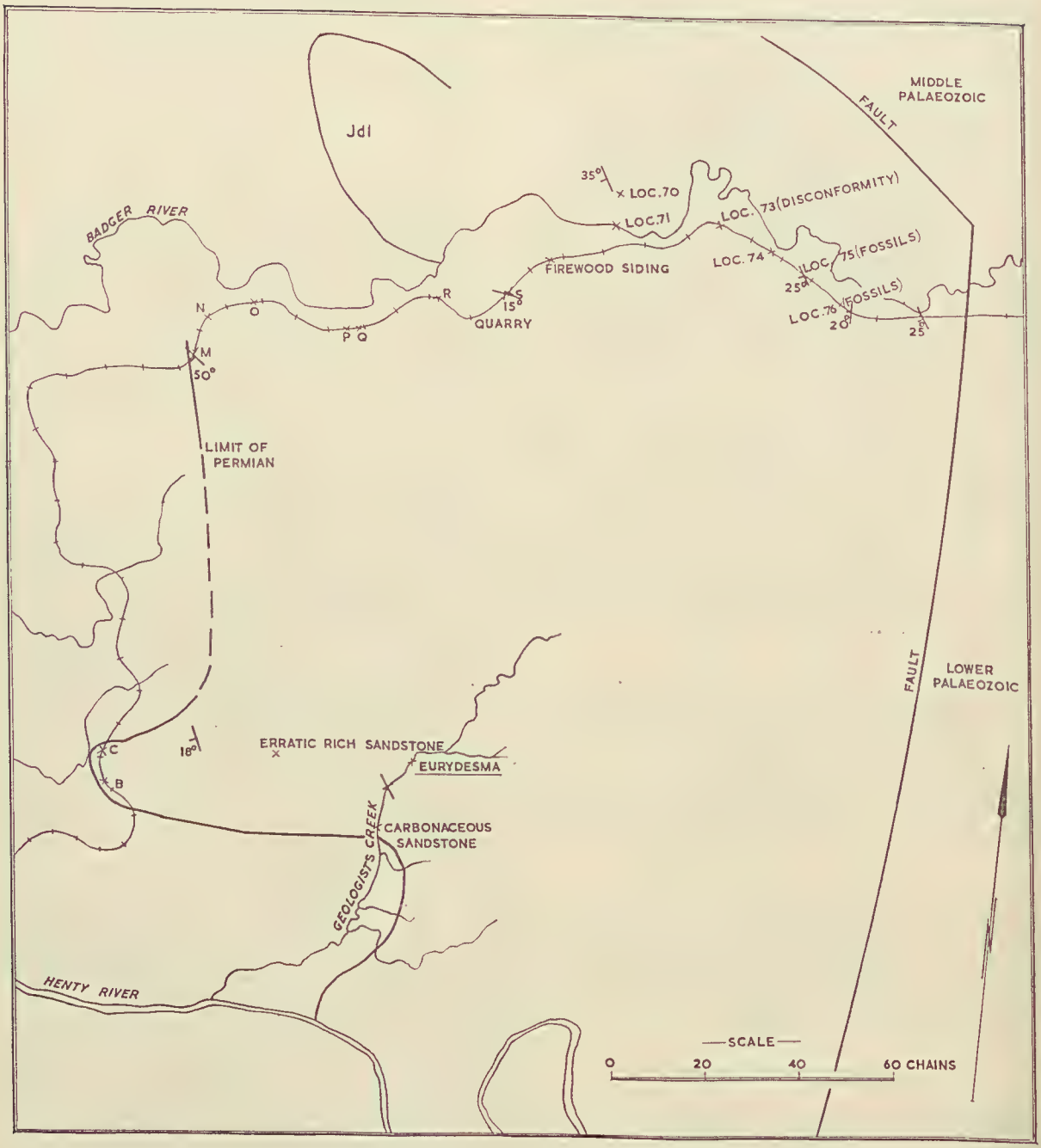



FIGURE 3

ston's specimens did not come from the railway cuttings, and on the grounds of Montgomery's description and Johnston's description, further supported by conversation with local residents, it is considered that they come from the flat ground on the north side of the Henty River, probably between Geologists Creek and the railway bridge. Thus, the coal measures referred to by Johnston as equivalent to the Mersey Coal Measures are thought to be below the marine beds but there are further coal measure beds above these marine beds and the present authors suggest that these are equivalent approximately to the Cygnet Coal Measures. Gill and Banks (1950, p. 266-7) described rocks from two formations close to Firewood Siding and suggested that the marine ones might be equivalent to the "Granton Formation" (= Cascades Group).

The present study was made in a traverse down Geologists Creek, in cuttings along the railway line and in a section along a creek flowing north into the Badger River just west of Firewood Siding (see map, figure 3).

Due to thick vegetation and flooding of Geologists Creek no measurements of thickness were possible. Sections of the upper coal measure beds in railway cuttings and a creek were made with a steel tape but due to faulting and irregularities in dip correlation between them is poor. Exposures of the marine beds in the railway cuttings were too discontinuous for measurement and the thickness is calculated trigonometrically. Localities mentioned are shown in the map (fig. 3).

The lowest formation in the section consists of carbonaceous, micaceous, quartz-rich sandstones which are well sorted. These occur in the lower part of geologists Creek where they are apparently associated with black shale containing *Glossopteris browniana, Gangamopteris spatula, G. obliqua* and *Noeggerathiopsis hislopi* (Montgomery, 1891, and Johnston, 1892).

This is followed after an interval with no obvious outcrop by alternating sandstone and fissile siltstone containing some fossils and a few erratics. In one place this shows north-west trending jointing planes less than a foot apart suggesting some faulting but there is no obvious displacement of beds and no change of dip. There follows a sandstone and siltstone alternation in which fenestellids, stenoporids, spiriferids and one specimen of *Eurydesma cordatum* were seen.

This is overlain by a fissile, calcareous siltstone containing spirifireds, stenoporids and predominant fenestellids. This is perhaps one of Montgomery's impure limestone beds.

After a further gap in the section the next unit is a buff sandstone with rare small erratics which forms small flats above creek level. This is richly fossiliferous with fenestellids, *Stenopora, Strophalosia* (?), *Terrakea, Dielasma,* spiriferids (including *Neospirifer*), *Spiriferellina, Ingelerella* and pelecypods. Of particular interest is the occurrence in bands of numerous small, inarticulate brachiopods.

A few feet above this and also forming a small flat area is a greyish feldspathic pebbly sandstone.

This is followed by a considerable thickness of greyish, feldspathic sandstone with numerous pebbles and small cobbles occurring in bands. The bedding in this sandstone is thick and the unit forms several large waterfalls. The final unit, exposed in the uppermost waterfall in the gorge of Geologists Creek, is a white, quartz-rich, well sorted sandstone with a few pebbles of white

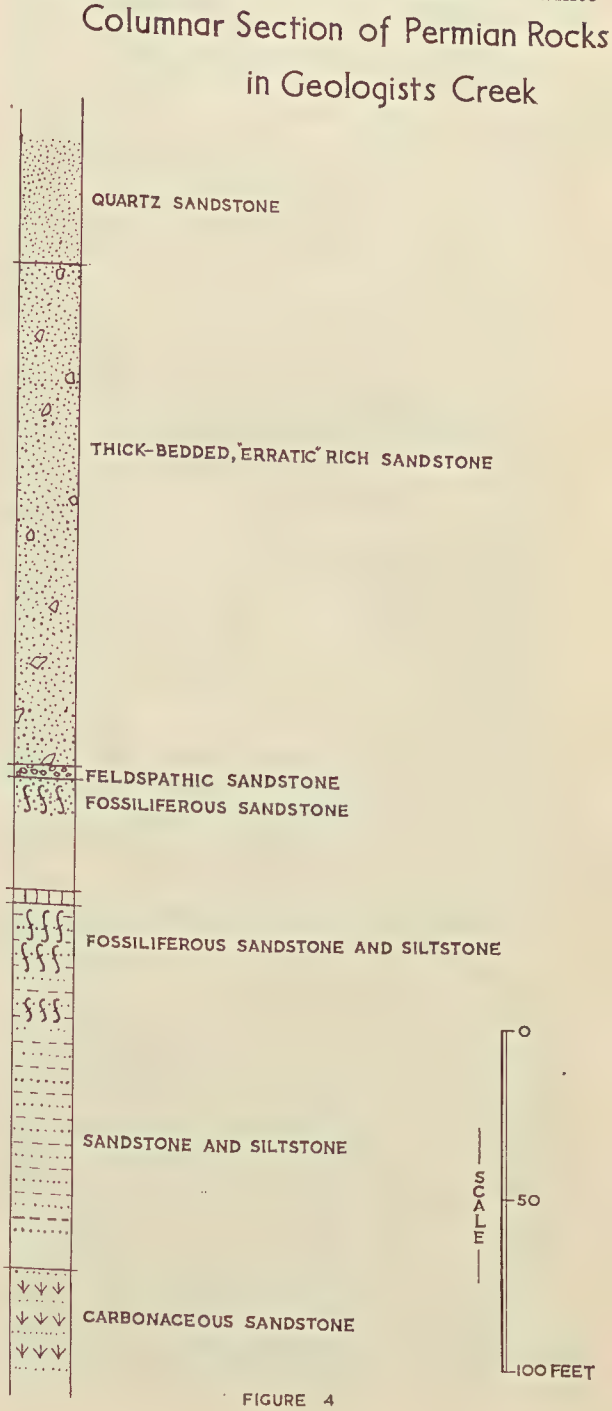



FIGURE 4

quartzite and this type of rock covers much of the surface between the Henty River and the railway line west of Firewood Siding. The basal sandstone and the plant-bearing shale formation is of the order of 40 feet thick and the marine sequence between the two formations of siliceous sandstone is of the order of 300 feet thick based on measurements of height of the top of the plateau cut in the Permian (525 feet above the level of the Henty River at the railway bridge) and on estimated heights in the gorge of Geologists Creek. The beds in the creek section are essentially horizontal. The thickness given is considerably in excess of that given by Montgomery which is thought to be much too small. The section in Geologists Creek is summarized in fig. 4.

In a railway cutting ("B") (Strahan 11, 3292, 1", E.N.E. of C.P. and see map, fig. 3) a section of Permian rocks is exposed. This shows:

Top—

20 feet: medium to fine grained feldspathic sandstone with occasional "erratics" or lenses of "erratics".

1 foot 8 inches: greenish-grey, medium-coarse grained sandstone with many erratics (up to 15 inches long) including quartzite, quartz schist, mica schist, chlorite schist and granite, very angular, un-oriented, unsorted; large (4" wide) *Ingelarella* (?) *subradiata* and other spiriferids.

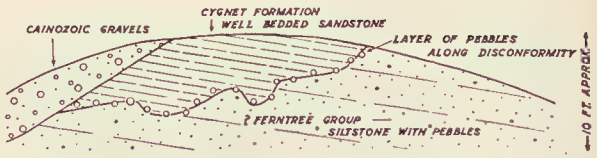
3 feet: dark-grey, medium-fine grained sandstone with pebbles and cylindrical bodies outlined by carbonaceous matter (? worm tubes).

4 feet: dark-greenish yellow sandstone with a few "erratics".

4 feet: greenish-yellow, fine-grained sandstone with occasional small angular and rounded "erratics".

The next cutting to the north ("C") also contains "erratic"-bearing sandstones but fossils are commoner and occur in lenses. The fossils include *Stenopora* (massive type like *crinita*, and ramose types), fenestellids, *Strophalosia*, spiriferids, including *Ingelarella subradiata, Spiriferellina, Aviculopecten*, other pelecypods, and calcareous worm tubes.

East of Firewood Siding a series of railway cuttings expose Permian beds. The easternmost one (co-ordinates 3.5 cms. S. CP. Zeehan 1,23435) contains alternating thick-bedded impure sandstone and fissile siltstone with sandstone predominating in thickness in the alternations. Pebbles up to an inch long are present but no fossils have been found. The boundaries between the members of the alternating beds are gradational. The next cutting west (Locality 76 of Gill and Banks, 1950, p. 267 and pl. III) contains fissile, grey, fossiliferous siltstone with a few pebbles interbedded with thin beds of feldspathic sandstone containing ostracodes and fenestellids. The fossils from these beds include *Fenestella, Polypora, Protoretepora, Stenopora, Ingelarella subradiata*, other spiriferids, *Schuchertella, Strophalosia, Merismopteria macroptera, Eurydesma cordatum, Edmondia, Chaenomya, Aviculopecten*, other pectinaceans. "*Platyschisma*" *oculus, Camptocrinus* and other crinoids and *Conularia inornata*. The pebbles include quartzite, schists and hornfels.




SKETCH OF DISCONFORMITY (Locality 73)

FIGURE 5

About forty yards from the eastern end of the cutting the fissile fossiliferous siltstones are overlain with a sharp contact by a bed of sandstone about a foot thick which grades up into a non-fissile siltstone, with a few "erratics" and no obvious fossils. Bedding is not clear and if present is thick to very thick. "Erratics" are up to eight inches long. Towards the western end of the cutting some bands of pebble occur in the siltstone as also do some bands of very thinly bedded siltstone without pebbles. These, however, are only a minor part of the sequence. In the next cutting west (co-ordinates 3.8 cms. S.W. of C.P., Zeehan, 1,23435; Locality 75 of Gill and Banks, 1950) thickly-bedded, grey siltstones with pebbles of schist which are well rounded and ellipsoidal, are associated with greenish-grey sandstone. *Fenestella, Strophalosia, Dielasma, Ingelarella oviformis, Spiriferina duodecimcostata* and other spiriferids are present. A fine-grained greenish-brown siltstone occurs in the next cutting to the west (Loc. 74 of Gill and Banks, 1950) and contains slightly-rounded pebbles of quartzite, schist and one large faceted cobble of grey granite eight inches long. Similar rock types occur west of the cutting (co-ordinates 5.2 cms. W.S.W., C.P., Zeehan, 1,23435; Locality 73 of Gill and Banks, 1950) where the "erratic"-bearing siltstones are overlain disconformably by well-sorted, thickly-bedded siliceous sandstone with carbonaceous fragments. The disconformity is marked by a narrow band of small siliceous pebbles (see fig. 5).

The apparent thickness of marine or "erratic"-bearing beds exposed is of the order of 800 feet. The section east of Firewood Siding is summarized as fig. 6.

The total thickness shown is thought to be excessive. Dips are up to 25°, indicating proximity to faulting, and possible faulting within the section. The numerous long gaps in the section in addition render the overall thickness quite unreliable and even the section is doubtful. Similar pebbly beds occur in some of the depressions south-east of the railway line where they outcrop beneath the quartz-rich sandstones. One such outcrop occurs at a locality 1" N.N.E. C.P. Strahan 11, 3293 and consists of grey, poorly-sorted sandstone with angular to sub-angular boulders of schist, slate, phyllite and quartzite.

Above the disconformity the basal beds are quartz-rich sandstones with carbonaceous fragments. These are thickly bedded and well sorted but have a few sub-rounded to rounded pebbles of quartz and quartzite. Between this cutting and Firewood Siding sandstone and fine-grained carbonaceous sandstone occur in the cuttings. At the

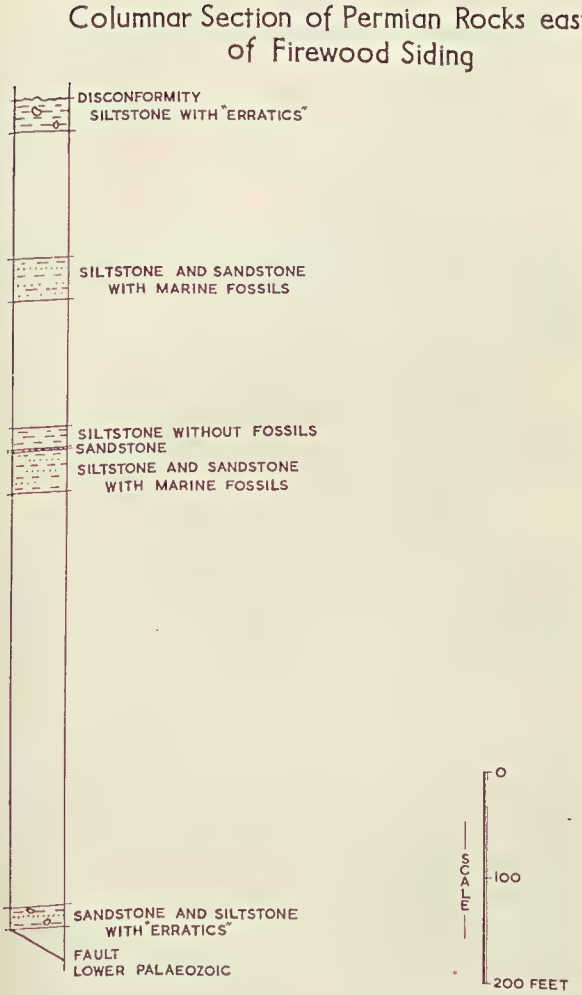



FIGURE 6

eastern end of the Firewood Siding cutting brown to gray micaceous sandstone outcrops. This is medium-grained and thinly-bedded with some cross-bedding in the thinner beds which have carbonaceous laminae. Plant fragments are present but not common. The rocks outcropping in the Badger River and on the cuesta to the north have been described earlier (Gill and Banks, 1950, pp. 266-67).

In the first cutting ("S") west of Firewood Siding (co-ordinates 3.4 cms. S.S.E. C.P. Zeehan Run 1, 23437) sandstone and pebbly sandstone are the main rock types with rare beds of carbonaceous siltstone. Cross-bedding dipping west or north-west is present.

In a small quarry south of the railway line about a hundred yards south-west of this cutting sandstone overlies a bed of grey, carbonaceous micaceous siltstone which is very rich in plant remains including *Glossopteris, Gangamopteris* and *Verterbraria.* Pyrite occurs associated with the carbonaceous siltstones.

The next cutting to the west ("R") (co-ordinates 3.5 cm. S.S.W. C.P. Zeehan Run 1, 23437) is thought to be that figured by David (1926, p. 102). At the eastern end of the figured cutting a bed of brecciated siltstone underlies a strongly-jointed sandstone in a small syncline. Just to the west in an anticline is sandstone with pebble bands and thin carbonaceous bands. Beyond a fault is a sandstone with a few thin carbonaceous siltstone bands, one of which shows circular, approximately horizontal sand-filled tubes, overlain by interbedded thin beds of sandstone and carbonaceous siltstone. To the west of another fault the basal section of the cut is in carbonaceous siltstone with the thin beds of sandstone overlain by two feet of sandstone, carbonaceous siltstone and finally 11 feet of thinly-bedded sandstone. In the basal siltstone unit there are worm tubes, current ripple marks (currents from west) and cross-bedding occurs in the sandstone layers indicating mostly currents from the east or south-east but some from the west. Next to the west is a fault zone in sandstone and carbonaceous siltstone. In the western section of the cut the basal portion consists of an alternation of thin beds of sandstone with very thinly interbedded sandstone and carbonaceous siltstone. This is overlain by a brecciated sequence of carbonaceous siltstone and thin sandstone bands. This is followed by several thick beds of sandstone which shows no brecciation or faulting like that in the underlying bed. The top unit in this part of the cutting is a thinly-bedded sandstone sequence.

Sandstone occurs in low cuttings further west in the axis of a flat anticline. The sandstone is medium-grained at the base and finer-grained and thinly-bedded above. In the next major cutting ("Q"), (co-ordinates 5.3 cm. S.W. C.P. Zeehan 1, 23437) a fault divides the cutting. At the eastern end there is a thickness of nine feet of medium-grained sandstone with thin bedding and cross-bedding mainly dipping south-west and overlain by nine feet of thinly-bedded fine-grained sandstone. Some cross-bedding dipping to the west and more rarely to the east occurs in the basal part. West of the fault the following section was measured:—

Top—

2 feet: Sandstone, white, micaceous, feldspathic, with clayey and carbonaceous partings producing flaggy breaks.

5 feet 6 inches: Brown and black carbonaceous and micaceous with minor superimposed on major rhythms. i.e., carbonaceous siltstone and siltstone alternate and each member consists of alternations of carbonaceous siltstone and siltstone; there are 8 cycles, the carbonaceous siltstone members being the thinner; a prominent sandstone band from 3′ 6″ to 4′ above the base.

3 feet: White, micaceous, feldspathic sandstone with thin bedding.

The basal sandstone contains bodies of concentric laminae of carbonaceous matter, the exact nature of which is unknown. The siltstones of the second

unit contain worm tubes and ripple marks and the top is brecciated and crumpled. This unit is very reminiscent of the brecciated beds in the previous cutting ("R").

Another section is exposed in the next cutting to the west ("P", co-ordinates 5.6 cms. S.W. C.P., Zeehan 1, 23437) and is as follows:—

Top—

1 foot 6 inches: Thickly bedded. medium-coarse grained feldspathic sandstone.

2 feet: Fine-grained, feldspathic, micaceous sandstone; quartz grains angular; cross bedding rare; flaggy splitting.

1 foot: Medium to coarse grained quartz sandstone with angular grains; thickness to 6 feet at east end of cutting.

3 feet: Black to brown, carbonaceous, micaceous, feldspathic siltstone, very thinly bedded with irregular bedding and some worm tubes.

3 feet 6 inches: White, friable, thinly bedded, flaggy-platy, feldspathic, micaceous sandstone becoming carbonaceous near the top; some bedding planes show rippling.

20 feet: (Top 4 feet in cut, bottom 16 feet in cliff to north) white, medium grained feldspathic sandstone.

Cross bedding in this cutting dips south-west, west and north-west.

A section was measured up the bed of a creek tributary to the Badger River, with the co-ordinates 4.6 cms. S.S.E. C.P. Zeehan 1, 23438 (on railway line). This section is given in detail below:—

Top—

Interbedded carbonaceous and non-carbonaceous siltstones with shattering, overthrusting, and normal faulting (as in section figured by David).

30 feet: Fine to medium grained, cross-bedded sandstone with quartz, feldspar, muscovite; thickly-bedded.

40 feet 2 inches: Medium to coarse-grained sandstone, with quartz, feldspar and a few quartz pebbles up to 30 feet above the base then some pebble bands, thickly bedded.

5 feet 9 inches: Coarse sandstone to fine conglomerate with large pebbles (up to 25 mms.) of quartz, red chert and quartzite; angular to sub-rounded pebbles; thickly bedded.

4 feet 9 inches: Fine to medium-grained quartz sandstone with a few pebbles of quartz and quartzite sub-angular to sub-rounded; thickly-bedded; flaggy to massive.

10 feet 9 inches: Brown-yellow, fine-grained quartz, mica, feldspar sandstone with very thin to thick bedding and some carbonaceous partings, flaggy and platy.

11 feet: Interbedded black micaceous siltstones with disseminated carbonaceous matter, and brown micaceous siliceous siltstones; very thinly bedded; distinct band of quartz pebbles 8 feet above base; some distinct plant fragments.

1 foot 3 inches: White to pink, medium-grained sandstone with conglomeratic bands with pebbles of quartz, quartzite and some schist; quartz, pink feldspar and muscovite in matrix; some carbonaceous partings.

2 feet: Greenish-grey sandstone with muscovite and biotite; fine-grained, angular grains; "erratics" present, especially about 18" above base, consist of quartz, quartzite, slate, argillite and pink granite.

The first unit is lithologically very like the beds below the disconformity east of Firewood Siding and distinct from those higher up. The higher units may be considered as parts of two cycles as under:—

8. Siltstone.
7. Fine to medium-grained sandstone.
6. Medium to coarse-grained sandstone.
5. Coarse sandstone to fine conglomerate.
4. Fine to medium-grained sandstone.
3. Fine-grained sandstone.
2. Siltstone.
1. Medium-grained sandstone.

The grain-size decreases upwards to unit 2 then increases upwards to unit 5 with higher decrease to unit 8. This latter is overlain by sandstones in the railway cuttings but the succession is broken. From the top of unit 8 to the highest point on the hills to the south on which the quartz-rich sandstones occur, is well over 50 feet so that a minimum thickness for this formation is 150 feet.

Further to the west (cutting "O", co-ordinates, 4.2 cms. S. C.P. Zeehan 1, 23438) white, siliceous sandstones outcrop. Some of these are pebbly and there are beds of siliceous and carbonaceous siltstones. Small limonitic concretions are present and there are also curved cylindrical worm burrows in it. Cross-bedding dips north-west to south-west with some dipping east, and ripple marks and slump structures are also present.

In the next cutting west ("N", co-ordinates 4.7 cms. S.S.W. C.P., Zeehan 1, 23438). a fault divides the cutting. At the eastern end of the cutting a cross-bedded sandstone is overlain by a micaceous sandstone containing plant fragments, a siltstone containing a sphenopsid, *Glossopteris*, both small and large species, and *Vertebraria*, and finally by a coarse sandstone with rare boulders up to four inches long. At the western end of the cutting the following section was measured:—

Top—

4 feet: White quartz sandstone, with much feldspar.

6 feet: Alternating fine micaceous sandstone and carbonaceous siltstone; sandstone beds ¼" to 2" thick, siltstone bands up to ¼" thick.

4 feet: White to brown carbonaceous, micaceous, feldspathic sandstone; carbonaceous partings and bands, thick bedding.

2 feet: Carbonaceous, micaceous, siltstone; thinly bedded.

4 feet 8 inches: Brown-yellow sandstone; fine to medium-grained; few quartz pebbles at 1' 6" above base sub-angular to sub-rounded; above this bed becomes more carbonaceous and micaceous with some plant remains.

6 inches: Carbonaceous ,micaceous brown-black siltstone with *Glossopteris, Gangamopteris, Vertebraria, Phyllotheca, Schizoneura,* and seeds.

5 feet: White, thick bedded sandstone, with fine conglomeratic bands of angular to sub-rounded quartz pebbles; cross bedding dipping south-west.

This section shows an alternation of sandstone and siltstone with some of the siltstone units themselves composed of alternating sandstone and siltstone beds. The sandstone units are consistently thicker than those of siltstone.

The final cutting in Permian rocks ("M", co-ordinates 5.5 cms. S.S.W. C.P. Zeehan 1, 23438) consists mainly of sandstone as shown in the following section.

Top—

1 foot: Cross-bedded, white, medium-grained sandstone.
2 ins.: Sandstone.
6 ins.: Clayey sandstone.
9 ins.: Sandstone.
1½ ins.: Clayey sandstone.
6 ins.: Sandstone, top surface ripple marked.
1 in.: Clay.
2 ins.: Sandstone.
4 ins.: Yellow clay.
9 ins.: Sandstone.
9 ins.: Micaceous, feldspathic sandstone with 1 in. clay seam.
1 foot 8 ins.: Yellow-brown limonitic, clayey sandstone.
6 ft. 8ins.: Yellow quartz sandstone with cross-bedding; muscovite and feldspar present, grains angular; bedding planes about 1 inch apart.
5 feet 1 in.: Conglomeratic sandstone; pebbles of quartz, quartz schist up to 1½ inches long, sub-rounded to sub-angular; matrix coarse sandstone to fine conglomerate, mainly quartz with some feldspar, very angular; lower surface uneven.
1 in.: White sandy micaceous clay.
2 feet 6 ins.: Medium-grained, micaceous (muscovite), feldspathic sandstone with occasional pebbles of quartz; grains angular; thickly bedded.

The prevalence of faulting, lack of distinctive marker beds, and common occurrence of cyclic sedimentation makes correlation between all these sections virtually impossible without very detailed work. On dip the last section ("M") should overlie the second last ("N") and this latter should overlie the creek section and due to lack of any possible correlation between them may well do so. However, the presence of faults is such that this superposition cannot yet be proved.

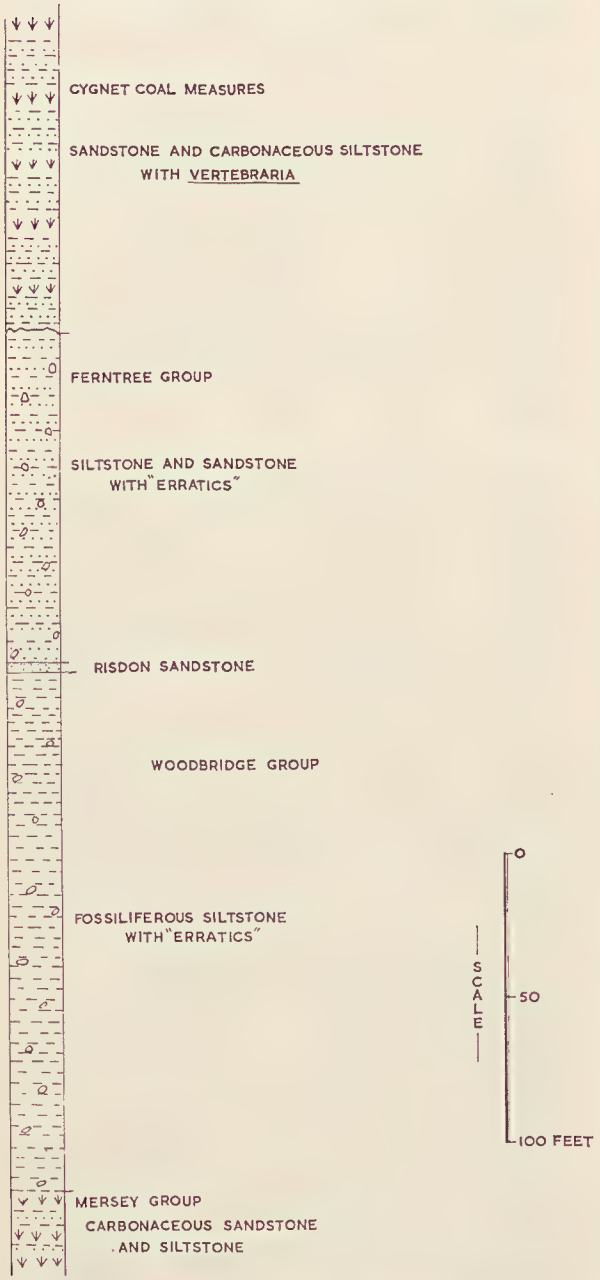
This, the highest formation in the Permian section in this area, consists of siliceous sandstones dominantly but with some minor conglomerates, mainly quartz-rich with some muscovite and feldspar, well-sorted, with some rounded pebbles of resistant types in a matrix of angular grains. Bedding varies from thin to thick and cross-bedding on a fairly fine scale is common. No consistent current direction is shown but currents from the eastern quarter seem to have been somewhat commoner than those from the west with very few from north or south. As exposed the sandstones are mainly white. Cyclic sedimentation is well shown in several sections with a major sandstone-siltstone alternation on which is superimposed finer alternations of fine-grained white siliceous sandstones with carbonaceous siltstones. These cycles represent changes in competency of the streams in the depositional area with perhaps the development of peaty swamps during times of low competence. The causes of the variations in competence may have been climatic or tectonic but more regional work is needed to establish the cause of the variation. There were at least three major cycles and many minor ones. The siltstones commonly show slumping, cross-bedding and ripple marking as well as the presence of worm tubes of several types. On at least one horizon plant remains are common and include *Glossopteris* spp., *Gangamopteris, Vertebraria, Phyllotheca, Schizoneura* and seeds.

The bores described by Twelvetrees (1902a, b, 1903) are of some interest although neither can now be located accurately. Eden Bore No. 1 was placed north of the railway line (and probably south of the Badger River) fifteen and a half miles from Strahan probably somewhere near cuttings M, N, O, as Eden Bore No. 2 was stated to be 1¼ miles further north-east on the Eden Coal Company's section (probably 4210, 43 M on the West Coast Mineral Chart) and must certainly have been south-west of the fault north of Firewood Siding. This means that Bore No. 1 was almost certainly not east of Cutting Q nor west of Cutting M. In Bore No. 1 it seems likely that the sandstones, shales and coal markings down to 115 feet belong to the topmost formation of the present authors. The beds from 115 feet down to 291 feet consisting of pebbly sandstone and mudstone may be the equivalent of the Ferntree Formation in the Geologists Creek section, the conglomerate between 291' and 309' to the Risdon Sandstone and the underlying pebbly and calcareous mudstones to the marine beds low in the Geologists Creek section. The order of thickness of the marine beds under this correlation is the same as that found in Geologists Creek. The correlations must, however, be regarded as very tentative only, in view of the lack of detailed information about the rocks in the bore. Eden Bore No. 2 passed through 108 feet of sandstone before entering a hard, indurated, broken-up slate which may well belong to the Eldon Group.

The Permian section in this area could be considered as consisting of five formations, a basal carbonaceous, micaceous well-sorted sandstone associated with plant-bearing shales, followed by poorly-sorted sandstones and siltstones with marine fossils, then an "erratic"-rich sandstone, a thick-bedded impure sandstone and finally a well-sorted siliceous sandstone with plant-bearing siltstones. The sequence is summarized in fig. 7.

The lowest formation, in addition to *Glossopteris* and *Gangamopteris,* contains *Noeggerathiopsis hislopi* which is known elsewhere in Tasmania from

the lower or Mersey Coal Measures, now roughly correlated with the Liffey Group of McKellar (1957) and the Faulkner Group of Banks and Hale (1957) The succeeding formation contains *Stenopora crinita* which occurse in formations above the Faulkner Group in the Hobart area and at Locality 76, *Schuchertella* and *Camptocrinus* not yet recognized above the Cascades Group in eastern Tasmania. Thus the Cascades Group may be represented here by sediments lithologically like the Malbina Siltstone and Sandstone in the Hobart area. A similar situation probably also occurs at Deloraine and in the Central Highlands.




Composite section of Permian System in Malanna Area

FIGURE 7

The thin, pebbly sandstone may be correlated on lithological and stratigraphical ground with the Risdon Sandstone but this is not at all certain. The thickly-bedded impure sandstones are in the stratigraphical position of the Ferntree Mudstone but are coarser and contain more pebbles. The uppermost formation has in addition to sphenopsids, *Glossopteris* and *Gangamopteris*, many specimens of *Vertebraria* which is known elsewhere in Tasmania from terrestrial sediments correlated with the Cygnet Coal Measures. Thus on the occurrence of *Vertebraria* this formation is correlated with the Cygnet Coal Measures in the south-east. In addition carbonaceous siltstone from this formation is considered (Balme, letter 18.6.1959) to be Upper Permian on palynological grounds.

In this area the marine beds and the correlates of the Cygnet Coal Measures all show signs suggesting closer proximity to the shoreline or source than those near Hobart. The " Woodbridge " correlate is rather coarser than its Hobart equivalent and in addition contains inarticulate brachiopods indicative of shallow water, perhaps shoreline conditions. The correlates of the Ferntree Mudstone are much coarser and contain more pebbles than that formation. The equivalent of the Cygnet Coal Measures has generally much coarser sand grains and a greater preponderance of pebbles and boulders than in the south-east. Of interest also is the fact that the marine beds estimated at 300+ feet thick, are thinner than at Hobart where corresponding beds total at least 885 feet thick.

### *SECTION ON MT. SEDGWICK.*

This seems to have been first noticed by Moore (1894, p. 148) who assigned a coal measure age (= Permian) to it. He became involved in a controversy with Montgomery (1894, p. 161) who suggested that the beds observed by Moore were due to Pleistocene redistribution of Permian material. Edwards (1941, pp. 19-22) also dealt with the area as part of an exhumed Permian or pre-Permian surface and correlated the beds on Mt. Sedgwick with Voisey's (1938) Achilles Stage on the grounds of the presence of *Spirifer* and *Aviculopecten*. Bradley (1954, p. 199) mentioned the Permian rocks briefly.

On the southern side of Mount Sedgwick (fig. 8) a section of Permian rocks is exposed in creek and cliff sections overlying quartz feldspar porphyries with slate fragments and overlain by dolerite which has baked the Permian. The dolerite contact is irregular and where best exposed is dipping west at a steep angle and cutting across the bedding. The Permian beds have a very low dip to the west. The basement on which the Permian rests varies considerably in height. Just east of Mount Sedgwick Owen Conglomerate occurs at least 200 feet

MAP SHOWING OCCURRENCE OF PERMIAN SOUTH OF MOUNT SEDGWICK (Based on air-photo, Lyell, Run 2, no. 774)

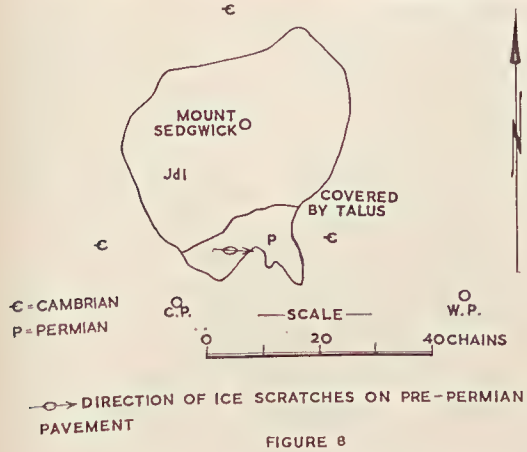



FIGURE 8

above the base of the Permian and has no Permian on it. Just to the west dolerite rests on porphyry about 20 feet above the base of the Permian and the Permian is absent. Thus it seems that there is either a valley in the pre-Permian surface at least 20 feet deep or a post-Permian graben. No evidence can be advanced as yet to favour either hypothesis. The depression occupied by the Permian is no more than 1,500 feet across (i.e., in an east-west direction).

On the southern side of Mount Sedgwick two streams flow south in the Comstock Valley. The section measured began on basement about 100 feet west of the easternmost and bigger stream. The section was carried to the north along cliff sections on the western side of the creek until a narrow shelf was reached which ran back to the foot of the dolerite cliffs. The section was carried north-westerly across this shelf and to the foot of a cliff in Permian then up this cliff to the dolerite contact. The total thickness measured between basement and dolerite was 210 feet approximately.

The contact between the Permian and the underlying rocks is exposed in a cliff section west of the creek mentioned above (1.8 cm., E.N.E., C.P., Lyell Run 2, No. 774). The contact is smooth and striated in some places but is jagged and irregular in other places within ten feet of the smoothed areas. Striations occur on both the slate fragments in the porphyry and on the porphyry itself but are clearer on the slate. The striations trend 106° and are deepest on the west side and shallowest towards the east thus indicating movement of the ice from west to east approximately. The contact is somewhat curved in section suggesting a *roche moutonnée* and it is perhaps significant that the surface is smoothed to the west and jagged to the east. Thus if the contact locally is the surface of a *roche moutonnée*, which cannot be positively established, the smooth upstream surface is to the west, the jagged plucked downstream surface is to the east, this agreeing with the evidence of the striations.

The basal Permian unit which is 39 feet thick (see text fig. 9) consists of well-striated boulders up to four feet in length consisting of porphyry, Owen Conglomerate, slates, quartzites and other rock types, in a poorly-sorted. dark-grey clayey matrix with poorly-marked horizontal fissility. No bedding was apparent. About six inches above the base at one place where the basement is jagged, there is a lense-like body of varved siltstone which is about six inches thick and about 30 inches wide. This lenticular body is slumped along the north-south axis. There is a slight disconformity just above the varved siltstone body. The basal unit is a tillite.

The second unit is a well-sorted pebbly tillite which is six feet thick. Much of the smaller material is lacking and the pebbles are well rounded. Faceting and striations are rare. No bedding is present. It is possibly an outwash deposit of supra-glacial material. This is followed by 14 feet of silicified conglomerate, rather resembling Owen Conglomerate, which differs from the underlying unit only in degree of silification. The next unit consists of six feet of compact conglomerate with small, rounded, mainly siliceous pebbles. This is well sorted. It tends to form the lip of a cliff. It is probably an outwash deposit. A thickness of 50 feet of unfossiliferous thickly-bedded, erratic-rich siltstone follows the conglomerate. The pebbles and boulders show some faceting and striations. This rock was possibly deposited by a floating ice sheet in very shallow water. There follows a thickness of 11 feet of conglomerate with somewhat rounded pebbles and few large boulders. This is possibly an outwash deposit.

The next unit represents a marked change in lithology. It is 11 feet thick and consists of dark-grey, fissile siltstone with a few small pebbles. Near the base this is unfossiliferous but higher up becomes fossiliferous, the main fossils being ramose stenoporids (*S. tasmaniensis*) but with some spiriferids and crinoids.

A limestone, 21 inches thick, succeeds the siltstone. It is medium to dark-grey in colour and fine-grained with a few rather rounded pebbles. Fossils are common and are dominantly stenoperids (*S. tasmaniensis*) although *Eurydesma cordatum* is common and crinoid plates are present. The *Eurydesma* shells are disarticulated and usually convex side up. The stenoporid colonies are broken and the crinoids fragmented.

The succeeding unit is about 63 feet thick and consists of a thickly-bedded, grey, pebbly siltstone with numerous fossils of which *Eurydesma cordatum* is prominent. However, spiriferids and stenoporids also occur in considerable numbers. The last unit is at least 11 feet thick and is a richly fossiliferous siltstone containing some erratics. Close to the dolerite contact it is baked and assumes a light-grey to creamy colour. It is thinly-bedded and rests on the underlying unit with a sharp contact. The fossils are dominantly ramose stenoporids (*S. tasmaniensis*) some of which show

## Columnar Section of Permian Rocks on Mount Sedgwick

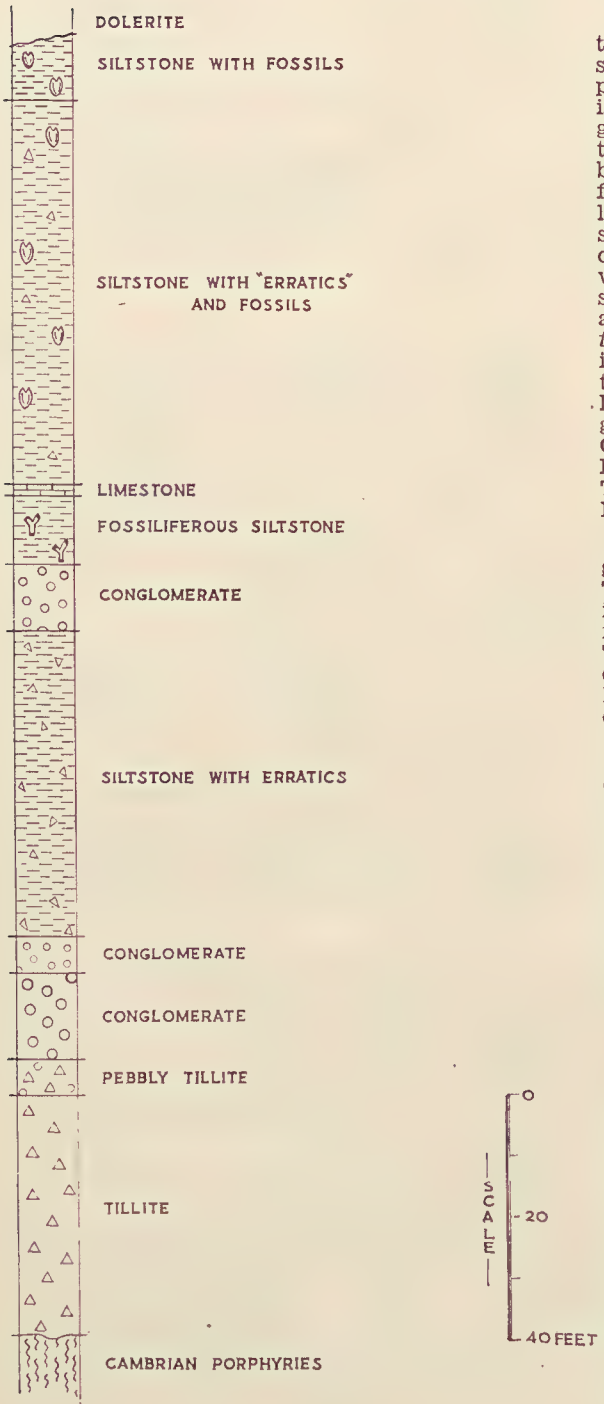



FIGURE 9

marked current orientation. Other fossils however are common and include fenestellids, spiriferids (including *Neospirifer*), *Eurydesma cordatum*, aviculopectinids and other pelecypods, *Peruvispira* and other gasteropods, and *Camptocrinus* and other crinoids (as disarticulated plates).

The succession consists of a basal formation of tillite and outwash conglomerate, then another similar formation differing from the lower one particularly in possessing bedding. The lower one is correlated on lithological and stratigraphical grounds with the Wynyard (= Stockers) Tillite and the higher one with the erratic-rich beds at the base of the Quamby Mudstone at Deloraine. The fissile siltstone which follows this is lithologically like the Quamby Mudstone. The succeeding limestone unit can be correlated with the basal limestone of the Golden Valley Limestone and Shale and with the Darlington Limestone as it is lithologically similar, occupies a similar stratigraphical position and contains *Eurydesma cordatum* and *Stenopora tasmaniensis*. The Darlington Limestone correlate is followed by a pebbly fossiliferous siltstone and this by a fossiliferous siltstone. These are correlated on stratigraphical and palaeontological grounds with the higher parts of the Golden Valley Group near Deloraine and the formations above the Darlington Limestone at Darlington (Banks, 1957). The section does not go high enough to include the Liffey Sandstone and its correlates.

The basal formation indicates initial terrestrial glaciation followed by an ice retreat (units 2, 3, 4). The next formation marks a second advance of the ice sheet which was possibly not grounded and was floating in a shallow water, possibly a marine basin. This second advance was less intense than the earlier one and the sheet thinner. This was followed by further retreat leading to the development of outwash. Shallow marine conditions succeeded the formation of outwash, in which the icebergs deposited small erratics in the silt. Then the limestone unit represents reduction in the amount of clastic material supplied to the site of deposition and rich marine life. Some icebergs were still present. The next formation indicated a third ice advance but in a deeper sea with icebergs depositing erratics. This third phase of the glaciation was less intense than either of the earlier phases. The topmost formation shows a decreased intensity of glaciation, possibly marking the retreat from the third phase maximum. Lack of outwash deposits also supports the idea of floating ice.

### *SECTION AT STRAHAN.*

This deposit was probably first noted by Moore (1896b, p. 74) in a paper read before the Royal Society of Tasmania in August, 1895, and by Officer, Balfour and Hogg (1895) who noted a "deposit of unstratified or faintly stratified clay of great hardness . . . " which contained some boulders which bore striae. They remarked that similar deposits occurred on Mount Sedgwick and Mount Tyndall. The Strahan deposits were considered to be Pleistocene by Moore because they contained no erratics "foreign to the country". Moore (1896b, p. 75) also noted another outcrop of a similar sort of rock two miles north-east of the outcrop being discussed on "Gould's old track". Lewis (1939, p. 165) commented on these deposits which he considered to be a Pleistocene moraine, associated with the "fluvio-glacial" terraces at Strahan.

Road cuttings on the Queenstown-Strahan Road between 3 miles and 1½ miles from Strahan expose a tillitic conglomerate. It shows some fissility and rough bedding which dips south-east at a low angle. This rock contains boulders up to two feet in length of greenish quartzite. quartz, very fine-grained black quartzite, slate, greywacke conglomerate like those of the Dundas Group and a biotite rich granite. Despite careful search no boulders of Owen Conglomerate or dolerite were seen. Some of the boulders are faceted and striated. The rock shows marked fracture planes and in places both matrix and boulders are badly shattered. There are a few beds of sandstone with rare rounded boulders and good bedding. On the whole sorting is very poor but there are lenses of comparatively well-sorted material which may be buried ice deposits or deposits of melt water streams. Boulders in the main body of the rock are more rounded than might be expected in a sub-glacial terrestrial till, and this rounding may have been produced by water transport.

On the first cutting south of the S 2 milepost steep faces trending 76° show slickensides which are either horizontal or dip slightly south and indicate north side west movement.

The present authors regard these beds as Permian because of their degree of lithification reflected in the fracturing of matrix and boulders, the jointing and the slickensiding. They have the same degree of lithification as is common in the known Permian beds in this region (e.g., the Firewood Siding and Geologists Creek area and on Mount Sedgwick) and considerably greater than that of the alleged Pleistocene beds at Strahan and Malanna. Lack of dolerite boulders and of Permian boulders also points to a Permian age but this lack can also be explained on the assumption of a Pleistocene age with a source in the West Coast Range just east of Strahan where neither Permian sediments nor dolerite are known. However. if the source was in this area the lack of Owen Conglomerate boulders is very difficult to understand. The slickensiding and movement implied by it are in keeping with slickensides and movements in the Permian near Firewood Siding. Thus the bulk of evidence suggests a Permian rather than Pleistocene age but no Permian fossils were found in it. This, however, is common in the glacial beds near the base of the Permian System in Tasmania.

The poor sorting of the bulk of the material together with faceting and striation of some boulders indicate some glacial transport. Increase in percentage of smaller boulders and clay and silt grades indicates some sorting, although of a low order, which is confirmed by crude bedding and sandstone layers. On the whole the deposit indicates the possibility of deposition in aqueous conditions of some of the sediment. Possibly these deposits were laid down by an ice sheet which was not thick enough all the time to remain grounded but when the ice sheet was grounded the meltwater lenses may have been deposited whereas when floating, the tillitic conglomerate was formed.

Lithologically, these beds resemble those between 65 and 115 feet above the base of the section on Mount Sedgwick (see fig. 9) and beds near the top of the Stockers Tillite and the base of the Quamby Mudstone in the Deloraine area.

## *SECTION AT POINT HIBBS.*

The only previous work on Permian rocks at Point Hibbs is that of Hills (1914) who noted the presence of fossiliferous mudstone conglomerate which he regarded as equivalent to the basal beds of the Permian System in other parts of Tasmania. His work was later quoted by Voisey (1938). The authors have examined the Permian section both north and south of Point Hibbs (see map, fig. 10).

On the northern shore the Permian is faulted against a Devonian limestone at the eastern end. Near the contact the limestone is sheared but the Permian is affected by the fault only to the extent of a shearing trending north-westerly in some of the finer beds near the contact. The Permian at the contact dips 275° at 85° and maintains this steep westerly dip for nearly a thousand feet. At this point it is affected by another fault and after a belt of variable strikes and dips some 20 yards wide maintains a dip of 38° to the south-west (237° to 255°) for about a hundred yards before dipping under dolerite. Almost at the dolerite contact the dip is 255° at 38° and the contact although irregular in detail, trends 318° over the length of its exposure on the shoreline. This trend would carry the contact west of Hibbs Pyramid, which is reported to be dolerite, so that there is probably either a marked swing in the trend or a fault. The dolerite has produced intense contact metamorphism in the Permian sediments for a hundred yards from the contact.

Because of the faulted contact with the Devonian limestone, the lower part of the Permian section may be missing. The lowest bed exposed is a conglomerate about two feet thick composed of numerous small angular rock fragments in a matrix of angular, coarse sand. The grains in the matrix are equant. There is no bedding within the unit but there is a north-west trending fissibility, probably due to shearing. The rock is medium-grey in

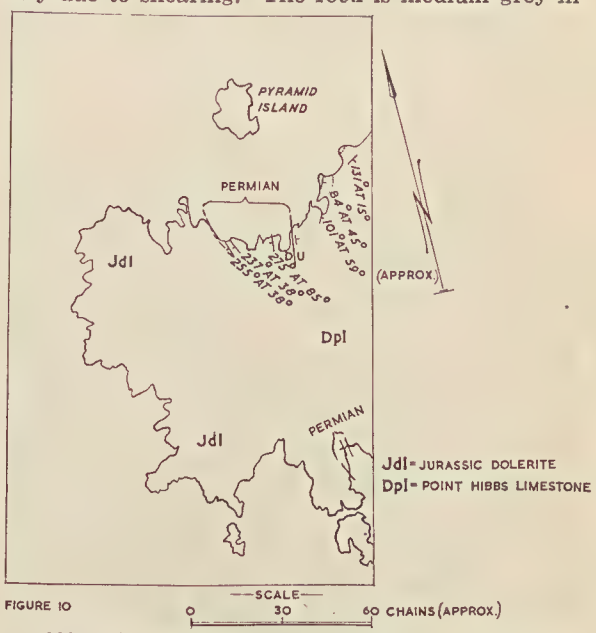



FIGURE 10

N.B.—The island shown as Pyramid Island should be called Hibbs Pyramid.

colour. Some of the boulders in it are striated and reach a length of one foot. One remarkable feature noticed was the lack of boulders of the adjacent limestone. This bed is overlain by 11 feet of conglomerate, interpreted as an outwash, which is relatively well sorted and contains somewhat rounded pebbles and boulders up to a foot long and lenses of tillitic material. The boulders include many of granite, some of a feldspar porphyry and quartzite including a green quartzite.

The outwash conglomerate is followed by 93 feet of tillite containing several thin beds of outwash conglomerate near the base. After a gap of 30 feet, siltstone outcrops for a thickness of 85 feet. This contains a lense of pyritic limestone twelve feet above the base and pyrite nodules at higher levels. It is a dark-grey, somewhat fissile rock with wavy laminations in places. A few pebbles which tend to be rounded occur near the base. A thinly-bedded siltstone unit 84 feet thick follows. The bedding is usually less than an inch thick but may reach two inches in thickness. Some of the siltstone is calcareous and there are a few cross-bedded sandy bands. Erratics are rare but pyrite nodules are common. The only fossils present are some worm burrows.

The next unit is 205 feet thick and consists of twenty alternations of fine-grained sandstone (or coarse siltstone) and " erratic "-rich sandstone in which the fine-grained sandstone is dominant as far as thickness is concerned. The fine-grained sandstone consists of angular, equant fragments of quartz, feldspar, rare white mica and carbonaceous material with a few erratics. It is medium-grey in colour and bedding planes are four inches to eight feet apart. It is brittle rather than fissile. Fossils are absent or rare in this rock type in the lower part of the unit but a little more common higher up. They include *Stenopora, Fenestella,* spiriferids, *Strophalosia, Eurydesma cordatum,* aviculopectinids, a euomphalid gastropod and crinoid columnals. Cross-bedded sets up to eight inches thick are present and the currents came from a southerly direction. One sandstone band about 10 feet thick above the base showed ripple marks with a trend of 340° when restored and cross-bedding formed by a current flowing from 225°. This sandstone contains plant fragments. Associated with the fine sandstone are at least twenty-one beds of " erratic "-rich sandstone which stands up several inches to two feet above the platform cut in the fine sandstone. These bands vary from six inches to nine feet thick. They are composed of the same minerals as the fine sandstone but they are perhaps a little coarser. In places the cement is calcareous. Bedding varies in thickness from six inches up to several feet. Their characteristic feature is that they contain numerous " erratics " up to four feet long which are angular to sub-angular and include granites, porphyries, quartzites, quartz, quartz schist, gneiss, green quartzite and rarely limestone like that immediately to the east. These " erratic "-rich bands are not tillites as they appear to contain little if any clay matrix and within any one band there is some sorting, although it is only middling good. Another feature of these bands is their richness in fossils especially *Eurydesma cordatum* and gastropods such as *Keeneia* but spiriferids, *Stenopora* and gastropods like *Peruvispira* also occur. The *Eurydesma* is articulated, disarticulated, or fragmented, the fragments lacking orientation. About 110 feet above the base the fine sandstone contains large limestone lenses with *Stenopora, Fenestella, Strophalosia,* spiriferids, *Eurydesma, Aviculopecten* and *Calcitornella.*

This unit of alternating sandstone and " erratic "-rich bands is followed by fifty-six feet of siltstone with rare erratics up to six inches long and numerous fossils. It is very dark grey. The siltstone contains rare small calcareous concretions which contain *Calcitornella* and numerous glendonites which are commonly single crystals up to six inches long and only rarely rosettes with up to three crystals. One glendonite grew around a specimen of *Eurydesma,* Fossils are very common and include numerous *Stenopora tasmaniensis,* fenestellids (very common in some bands), spiriferids including *Grantonia, Neospirifer* and *Ingelarella, Eurydesma cordatum, Notomya,* aviculopectinids and *Keeneia.* The numerous extensive colonies of *Stenopora tasmaniensis* are preferentially oriented in many places suggesting currents from the north-west, north or north-east.

The next unit, which is 430 feet thick consists of four cycles, each cycle consisting of a basal member of banded conglomeratic siltstone and siltstone and the higher one of siltstone. The lowest cycle is 65 feet thick and of this 59 feet are conglomeratic siltstone and siltstone and six feet of silstone. In the second cycle there are nine feet of siltstone and conglomeratic siltstone and then 37 feet of siltstone. The next cycle is 125 feet thick with the basal member 103 feet thick and the upper one 22 feet thick. The final cycle is 295 feet thick with a basal member only five feet thick. There is a further major cycle in that in the first and third cycles the basal member is the thicker one while in the second and fourth the upper member is the thicker.

The lowest cycle contains numerous fossils, especially in the pebbly bands, and these include *Eurydesma cordatum, Keeneia platyschismoides, Stenopora tasmaniensis,* spiriferids, *Peruvispira* and fenestellids. The siltstones have wavy laminations. In the basal member of the third cycle fossils are again very abundant on some horizons and in the top member an 18-inch-thick limestone bed occurs. This is very impure and contains numerous " erratics ". Fossils are not common in the limestone but include worm burrows and a bilaminar *Stenopora* very like *S. johnstoni.* The higher member of the fourth cycle is fossiliferous and the fossils include *Stenopora* and *Eurydesma.* Erratics up to 18 inches long occur in the siltstone member and a band of " erratics " occurs 146 feet above the base of the member. Erratics again become common near the top of the formation.

The belt of shattering and variable strike interrupts the section at this level. Beyond it at least 200 feet of alternating sandstone and siltstone occur in which the beds are usually two to three feet thick but one more than 20 feet thick is present. Bands of pebbles are present in the sandstone and erratics are present in the siltstone. The erratics are dominantly quartzite and are up to six inches long. Fossils are abundant on some horizons. They include gastropods, fenestellids, *Stenopora Aviculo-*

# SECTION OF PERMIAN ROCKS ON NORTH SIDE OF POINT HIBBS

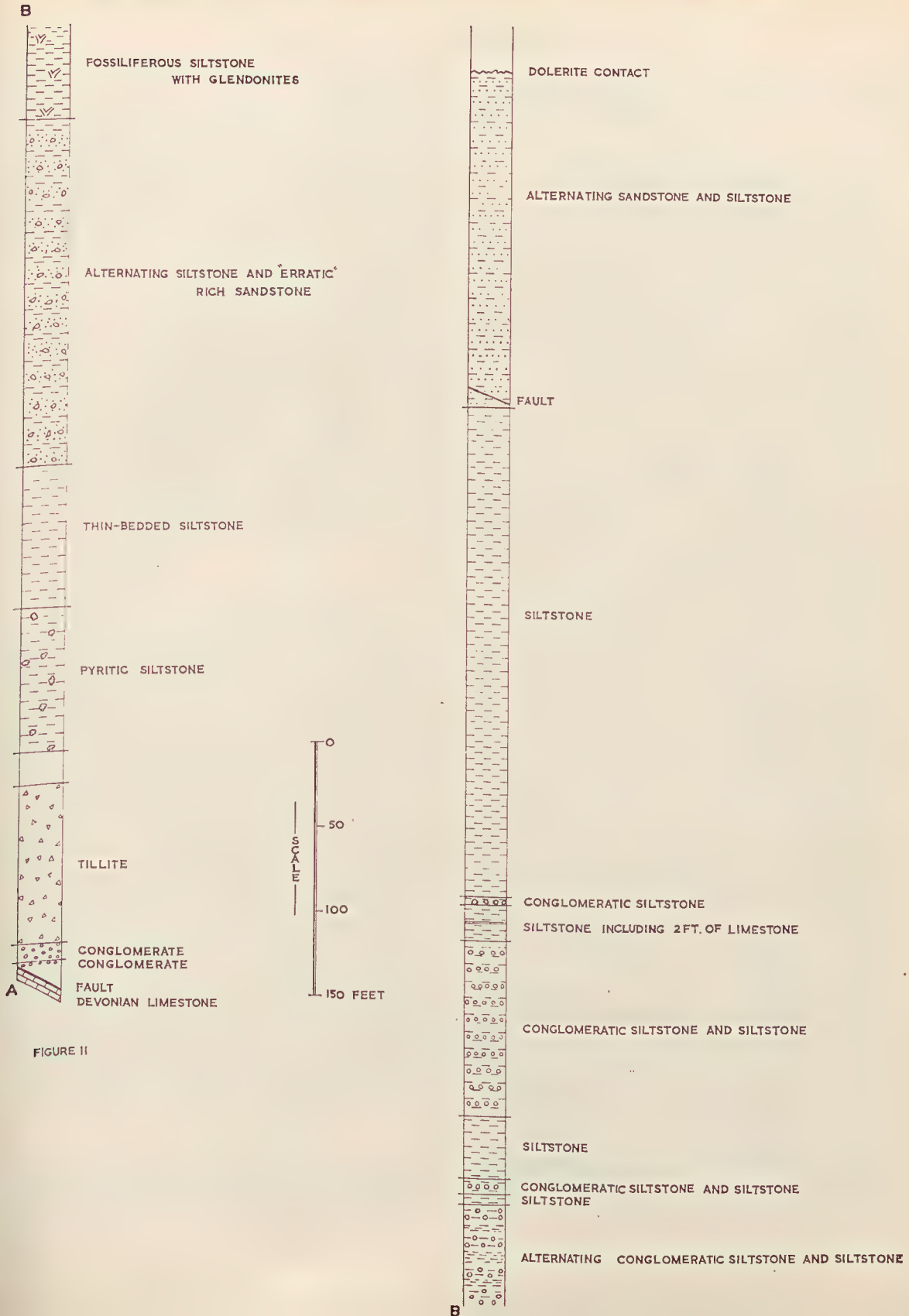



FIGURE 11

*pecten subquinquelineatus, Eurydesma cordatum, E. cordatum* var. *sacculum* and spiriferids including *Ingelarella*. The section is terminated by a dolerite intrusion.

The Permian section on the north shore of Point Hibbs is summarized here as fig. 11.

It will be seen that at least 1,200 feet of clastic sediments are present. The lowest 106 feet of dominantly glacial origin, might be correlated with the Wynyard Tillite. The next major unit could be considered as composed dominantly of pyritic siltstone with some calcareous concretions and rare sandstone bands. It is at least 174 feet thick but there is a 20-feet gap between it and the underlying formation. This might be considered on lithological and stratigraphical grounds as equivalent to the lower part of the Quamby Group (= Quamby Mudstone of Wells, 1957) and the Woody Island Siltstone. The next major lithological break is at the top of the alternating sandstone and pebbly sandstone, 205 feet thick. Fossils become abundant in the next unit, 56 feet thick, which consists of siltstone with glendonites. The fossils indicate a position low in the Permian sequence in Tasmania and the presence of glendonites strongly suggests correlation with part of the Woody Island Siltstone as these pseudomorphs are known from this formation and its correlates in eastern and northern Tasmania. The formation showing the four cycles follows this and is 430 feet thick. The thin limestone bed in the third member may be the Darlington Limestone as it is roughly in the correct stratigraphic position and contains some of the fossils from that formation. However, this cannot be regarded as established. It occurs within a unit 20 feet thick of siltstone much more richly fossiliferous than the adjacent beds and this strengthens the correlation with the Darlington Limestone. If the richly fossiliferous beds elsewhere are accepted as being at or near the base of the Golden Valley Group (= Formation of Wells, 1957), the base of the correlate of this group in the Point Hibbs area might well be considered as the base of the 20 feet of richly fossiliferous beds. The beds above this 20-feet unit consiting of at least 44 feet of alternating siltstone and conglomerate then sandstone and siltstone might then be considered equivalent to the higher units of the Golden Valley Group such as the Macrae Mudstone and Billop Sandstone of McKellar (1957) and the Bundella Mudstone of Banks and Hale (1957). The Mersey Group of fresh-water beds does not seem to be present but it is not impossible that they are represented here by marine sediments.

Permian rocks also occur on the south side of Point Hibbs (see fig. 10). They are faulted on the east against Devonian limestone which dips steeply east, and are intruded on the west by dolerite. The total thickness would not exceed 300 feet of which 250 feet are exposed in the shore section at the head of the bay. The Permian itself dips steeply to the east near the limestone and is apparently overturned and on the west side of the bay dips west at about 80°. The lowest (i.e., easternmost) exposed bed is a pebbly sandstone with fragmentary fossils. Higher up are siltstones with erratics and some beds of limestone. *Stenopora tasmaniensis* is particularly common in these. The topmost unit consists of interbedded pebbly sandstones and siltstones. The sandstones are richly fossiliferous . The dolerite has highly indurated the sandstone. Fossils in the Permian rocks in this bay include *Stenopora tasmaniensis, S. johnstoni* and a fine ramose stenoporid, fenestellids, *Strophalosia*, spiriferids including a large *Ingelarella*, pelecypods including numerous large *Eurydesma cordatum* and aviculopectinids and gastropods . The beds close to the western side of the bay where limestone is commonest are probably close to the Darlington Limestone in age judging from the presence of *S. johnstoni* and the lowest beds exposed would be about the level of the "Erratic Zone" on Maria Island.

One feature of the Point Hibbs section is the cyclic sedimentation. On a fine scale there are alternations of siltstone and sandstone, siltstone and conglomerate or sandstone and pebbly sandstone. In many cases fossils are much commoner in the pebbly beds but this is not invariable as some of the siltstones with few erratics are also fossiliferous. These alternations are themselves grouped into larger cycles with the banded sediments alternating with siltstone. On an even greater scale the succession may be considered as glacial beds, followed by siltstone, banded sandstones, siltstone, and then five cycles of alternating banded siltstone and siltstone. Explanation of these cycles requires more regional data than it is appropriate to present here.

## SUMMARY AND CONCLUSIONS.

Permian tillite and fossiliferous siltstone occurs on the western end of Mount Read occupying depressions in a partly exhumed pre-Permian surface of Dundas Group rocks. The section is not clear but the Wynyard Tillite and Quamby Group are thought to be represented. At Mount Sedgwick the Permian rests on a striated surface of Dundas Group rocks. The striations indicate movement of ice from west to east. The section includes a basal tillite then rocks of the Quamby and Golden Valley Groups but these are considerably thinner than in eastern and north-western Tasmania. Near the mouth of the Henty River Permian rocks are faulted against older Palaeozoic sediments. The oldest Permian rocks recognized are correlated with the Mersey Group and include some coal. These are followed by the "Woodbridge" Group, Ferntree Group and Cygnet Coal Measures. All these groups are thinner than in south-eastern Tasmania and generally of coarser grainsize. Near Strahan a fluvio-glacial conglomerate occurs and is correlated with the top part of the Wynyard Tillite. At Point Hibbs a section from somewhere within the Wynyard Tillite up to at least into the Golden Valley Group is well exposed. The Quamby and Golden Valley Groups are comparable in thickness with their equivalents near Deloraine and Cressy and perhaps thicker than the sections in south-eastern Tasmania (see fig. 12).

Evaluation of these variations in thickness must await more regional data.

## GEOLOGICAL HISTORY.

It would appear from the evidence quoted earlier that early in the Permian Period, Western Tasmania was covered by an ice sheet which in places moved

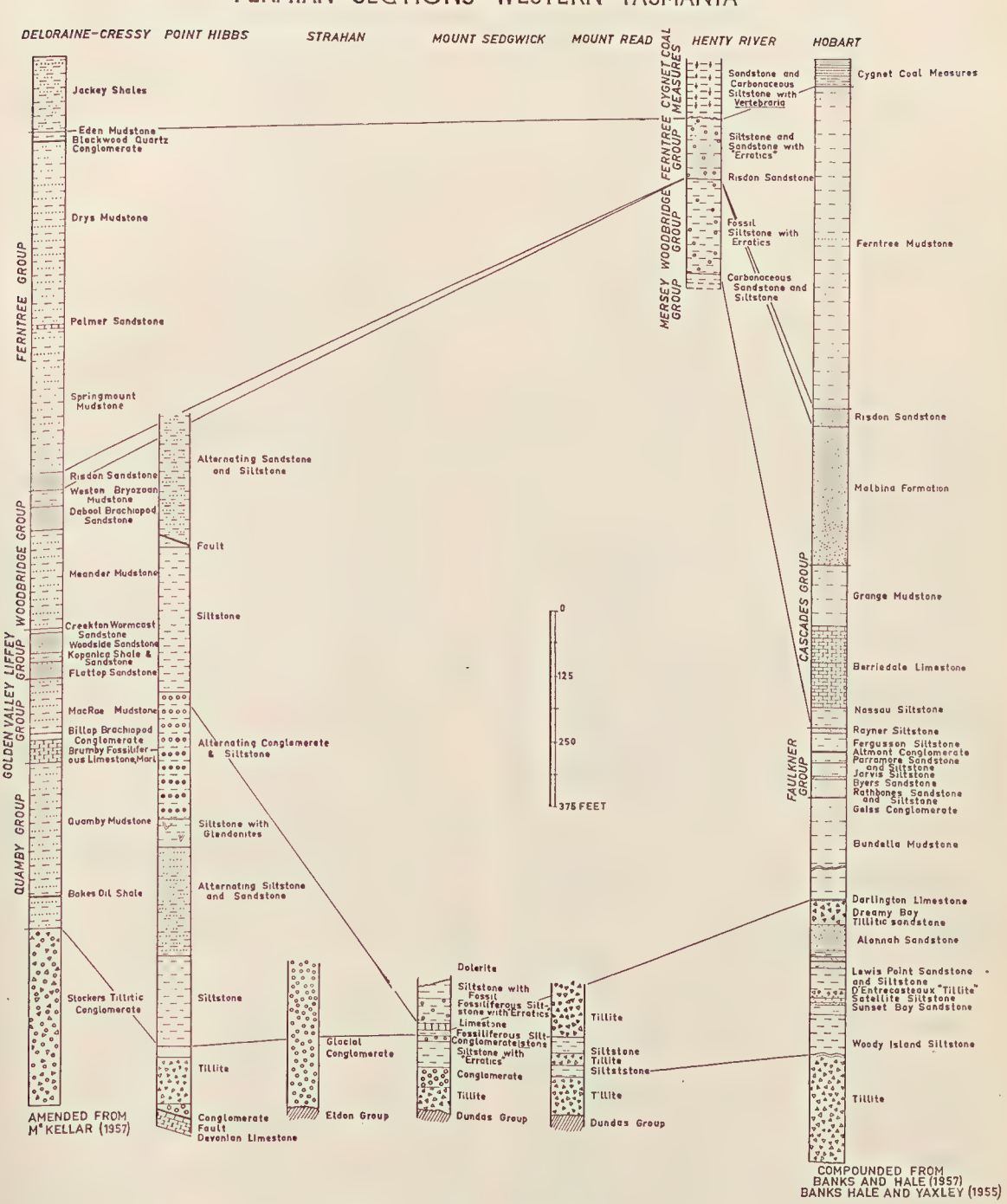

PERMIAN SECTIONS WESTERN TASMANIA
DELORAINE-CRESSY
POINT HIBBS
STRAHAN
MOUNT SEDGWICK
MOUNT READ
HENTY RIVER
HOBART
FERNTREE GROUP
GOLDEN VALLEY GROUP
LIFFEY GROUP
WOODBRIDGE GROUP
QUAMBY GROUP
Jackey Shales
Eden Mudstone
Blackwood Quartz Conglomerate
Drys Mudstone
Palmer Sandstone
Springmount Mudstone
Risdon Sandstone
Weston Bryozoan Mudstone
Debool Brachiopod Sandstone
Meander Mudstone
Creekton Wormcast Sandstone
Woodside Sandstone
Kopaniog Shale & Sandstone
Flattop Sandstone
MacRae Mudstone
Billop Brachiopod Conglomerate
Brumby Fossiliferous Limestone, Marl
Quamby Mudstone
Bakes Oil Shale
Stockers Tillitic Conglomerate
Alternating Sandstone and Siltstone
Fault
Siltstone
Alternating Conglomerate & Siltstone
Siltstone with Glendonites
Alternating Siltstone and Sandstone
Siltstone
Tillite
Conglomerate
Fault
Devonian Limestone
Glacial Conglomerate
Eldon Group
Dolerite
Siltstone with Fossil Fossiliferous Siltstone with Erratics
Limestone
Fossiliferous Siltstone with Erratics
Conglomerate
Tillite
Dundas Group
Tillite
Siltstone
Tillite
Siltstone
T'llite
Dundas Group
0
125
250
375 FEET
AMENDED FROM M° KELLAR (1957)
MERSEY GROUP
WOODBRIDGE GROUP
FERNTREE GROUP
CYGNET COAL MEASURES
Sandstone and Carbonaceous Siltstone with Vertebraria
Siltstone and Sandstone with "Erratics"
Risdon Sandstone
Fossil Siltstone with Erratics
Carbonaceous Sandstone and Siltstone
Cygnet Coal Measures
Ferntree Mudstone
Risdon Sandstone
Melbina Formation
CASCADES GROUP
Grange Mudstone
Barriedale Limestone
Nassau Siltstone
Rayner Siltstone
FAULKNER GROUP
Fergusson Siltstone
Altmont Conglomerate
Parramore Sandstone and Siltstone
Jarvis Siltstone
Byers Sandstone
Rathbones Sandstone and Siltstone
Galss Conglomerate
Bundella Mudstone
Darlington Limestone
Dreamy Bay Tillitic sandstone
Alonnah Sandstone
Lewis Point Sandstone and Siltstone
D'Entrecasteaux "Tillite"
Satellite Siltstone
Sunset Bay Sandstone
Woody Island Siltstone
Tillite
COMPOUNDED FROM BANKS AND HALE (1957) BANKS HALE AND YAXLEY (1955)

FIGURE 12.

from west to east over a surface with a relief of possibly a couple of hundred feet. On the evidence of the boulders present in the basal tillite and overlying fluvio-glacial or glacial beds the area overridden by the ice included conglomerates like the Owen Conglomerate, grewacke conglomerates like those in the Dundas Group, quartzites like those in the Eldon Group, some of them with fossils, black quartzites, green sandstone, slates including black slates, porphyries of several types including feldspar porphyries and a biotite rich granite. The lack of erratics similar to local Precambrian rocks is remarkable.

The ice later retreated depositing a sequence of glacial and fluvio-glacial beds. At least one readvance of the ice sheet is recorded in the section on Mount Sedgwick. Following retreat of the ice, sands and pebbly sands were deposited in a cyclic fashion, the cycle representing perhaps minor retreats and advances of the glacial front or influx of turbidity currents into the area from time to time. At Point Hibbs at least these sands were marine. "Erratics" of quartz schists and gneiss of a local Precambrian type occur at this level. Perhaps contemporaneously at Mount Sedgwick pebbly silts were being deposited.

Further retreat of the ice front led to deposition of siltstones containing few erratics, calcareous concretions and glendonites. This type of rock is much thicker at Point Hibbs than at Mount Sedgwick where it also lacks the glendonites, and concretions. These siltstones are marine and were probably formed under conditions of poor circulation. .They contain no structures or fossils characteristic of deep water but at the same time contain no clear evidence of shallow water deposition.

There is a break in the record of Permian sedimentation in Western Tasmania in the next rocks exposed being the lacustrine and paludal beds of the Mersey Coal Measures. These terrestrial conditions were followed by an inundation of the land by the sea. Pebbly siltstone, sandstone and impure limestone were deposited and at times marine life was abundant . It was mainly of shallow water benthonic forms. Some evidence suggests that this area was closer to the source and that the sea was shallower than at Hobart. After retreat of the sea erosion occurred before deposition of pebbly sands, silts and carbonaceous silts in lakes and swamps. There were several variations in the competency of the currents in the area of deposition. Plant life was abundant and included pteridosperms and equisetales.

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## LOCALITY INDEX.

| | | | | | |
|---|---|---|---|---|---|
| Badger River | Strahan | 41° | 59′ | 145° | 14′ |
| Comstock Valley | Lyell | 42° | 02′ | 145° | 39′ |
| Darlington | Maria Is. | 42° | 35′ | 148° | 04′ |
| Deloraine | Quamby | 41° | 31′ | 146° | 22′ |
| Derrinal, Victoria | — | 36° | 53′ | 144° | 36′ |
| Firewood Siding | Zeehan | 41° | 59′ | 145° | 16′ |
| Geologists Creek | Strahan | 42° | 00′ | 145° | 16′ |
| Henty River | Strahan | 42° | 02′ | 145° | 18′ |
| Hobart | Hobart | 42° | 52′ | 147° | 20′ |
| Malanna | Zeehan | 41° | 59′ | 145° | 13′ |
| Maria Island | Maria Is. | 42° | 37′ | 148° | 06′ |
| Moores Pimple | Zeehan | 41° | 02′ | 145° | 28′ |
| Mount Dundas | Zeehan | 41° | 52′ | 145° | 29′ |
| Mount Hamilton | Murchison | 41° | 50′ | 145° | 30′ |
| Mount Read | Zeehan | 41° | 50′ | 145° | 30′ |
| Mount Sedgwick | Lyell | 42° | 00′ | 145° | 35′ |
| Mount Tyndall | Murchison | 41° | 57′ | 145° | 3′4 |
| Pieman River | Pieman River | 41° | 40′ | 145° | 02′ |
| Point Hibbs | Pt. Hibbs | 42° | 43′ | 145° | 15′ |
| Strahan | Strahan | 42° | 10′ | 145° | 20′ |
| Zeehan | Zeehan | 41° | 53′ | 145° | 17′ |

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# THE MALBINA SILTSTONE AND SANDSTONE

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## ABSTRACT

The Malbina Siltstone and Sandstone overlies the Cascades Group and underlies the Risdon Sandstone in the Hobart area, Tasmania. This unit has been called "Woodbridge Glacial Formation" and other names. In the type section five members can be recognized:—"A", a basal sandstone; followed by "B", a siltstone; "C", a thin-pebbly sandstone; "D", a siltstone; and "E", the uppermost richly fossiliferous sandstone and siltstone. Some of the sandstone beds are poorly sorted and graded. The silts were deposited in fairly deep water and deposition of silt was interrupted from time to time by inrushes of turbidity currents bringing pebbles, sand and shells from shallower water. Erratics indicate the presence of rare icebergs. The formation is Upper Artinskian or Kungurian.

## INTRODUCTION

This formation was first recognized by Voisey (1938, p. 313) who referred to it as the 'Woodbridge Glacial Stage". Lewis (1946, p. 22) called it "Lindisfarne Conglomerate Stage" but was not consistent (see Smith, 1959, pp. 148-149) so that Prider (1948, p. 34) suggested the retention of Voisey's term, which was amended to "Woodbridge Glacial Formation" by Hills and Carey (1949, p. 31) and used in that form by a number of later authors.

McKellar (1957) used the term "Woodbridge Group" for the rocks between the Liffey Group and the Ferntree Group in the Western Tiers. In terms of the Hobart succession his "Woodbridge Group" would probably be equivalent to the top of the Faulkner Group, the Rayner Sandstone, Cascades Group of Banks and Hale (1957) and the formation here called Malbina Siltstone and Sandstone.

The term "Woodbridge" was first used by Lewis (1937, p. 434) for rocks at Woodbridge which he correlated with rocks at Cape Lamanon on the basis of the presence of "erratics" in both. The "Cape Paul Lamanon Series" is probably equivalent to the Malbina Formation as here used but has not been carefully studied. The "Woodbridge Series" at Woodbridge is an unbedded, poorly-sorted, ungraded rock with numerous striated and facetted pebbles and is a true tillite. It is lithologically quite distinct from the bedded, fossiliferous, pebbly sandstones and siltstones of the "Woodbridge Glacial Formation" in the Hobart area. In the Woodbridge area the section is not clear but the tillite appears to be overlain at some distance by a mudstone identifiable on fossil evidence as Bundella Mudstone. In this same area rocks having the lithology and fossils of the Malbina Formation overly the Cascades Group which rests in turn on the Faulkner Group which contains typical carbonaceous siltstones near Oyster Cove Post Office. The Faulkner Group overlies, in turn, the Bundella Mudstone. It is, thus, very unlikely that the "Woodbridge Series" at Woodbridge and the "Woodbridge Glacial Formation" are the same formation or correlates. The "Woodbridge Series" is probably equivalent to the Wynyard Tillite at the base of the Permian succesion in Tasmania.

It seems wisest to discontinue the use of the term "Woodbridge" except for the tillite at Woodbridge. The formation called "Woodbridge Glacial Formation" in the Hobart area is here named the "Malbina Siltstone and Sandstone" to which the "Cape Paul Lamanon Series" may be equivalent. The "Woodbridge Group" of McKellar should be given a different name.

When Banks and Hale described the Permian sequence in the Hobart area in 1957 they were unable to quote a suitable type section for the "Woodbridge Glacial Formation". Every section examined at that stage was unsuitable because of lack of outcrop, lack of base or top, or faulting.

During 1959 Read mapped the area west of Granton as part of an honours course in geology at the University of Tasmania. A good section in and around Jarvis Creek (see map, fig. 1, Banks

and Hale, 1957) was found and then surveyed in detail by both authors. The section occurs on the hill slopes west of Jarvis Creek and in the bed of Fergusson Creek and the southern slope of the valley of Fergusson Creek just above its junction with Jarvis Creek. Thicknesses were measured by level and staff and thicknesses between stations on steep slopes or cliffs with a steel tape. A dip of 3½° degrees to the south-west was used in the thickness calculations. It is unlikely that any of the thicknesses are in error by as much as a foot and many of them are in error by less than an inch. The authors wish to acknowledge their indebtedness to Dr. E. Williams, now of the Geological Survey of British Guiana, for many stimulating discussions on the conditions of formation of the unit being discussed, and to Mr. A. H. Spry for assistance with the mineral identifications and helpful comments on the manuscript and to Professor S. W. Carey for helpful criticism.

## STRATIGRAPHY

The Malbina Siltstone and Sandstone is defined as that formation of siltstone and sandstone 300 feet thick which conformably overlies the Grange Mudstone and underlies the Risdon Sandstone in Jarvis Creek (co-ordinates 50422.73528). The name is derived from the old Malbina Cemetery nearby. The formation contains *Stenopora crinita, Strophalosia typica* and *Strophalosia ovalis* and is Upper Artinskian or Kungurian in age.

In the type area the formation can be divided into five members, A, B, C, D, E, which can also be recognized in the South Arm area (see Green, 1961) and at Eaglehawk Neck.

### Member A

The lowest member ("A") is composed of sandstone with subordinate siltstone and is about 130 feet thick. The detailed section is given as Appendix A.

Coarse sandstone occurs on four horizons, the main development being that of unit 19 which probably consists of three beds each of which have fossils and pebbles at the base. The coarse sandstone units vary from 0.10-5.00 feet in thickness, averaging 0.97 feet thick in Member A and 1.34 feet thick in the whole formation. Medium sandstone is more common (22% approx. of Member A, 11.5% approx. of whole formation) than the coarse sandstone. The beds of medium sandstone vary from 0.20-2.30 feet thick, averaging 1.34 feet thick in Member A, 1.20 feet in the whole formation and having a modal thickness of beds of 1.0 feet. Fine sandstone forms 46% of Member A, 29% of the whole formation. It occurs in beds from 0.10-4.40 feet thick, averaging 1.19 feet for Member A and having a modal thickness of 0.5 feet for Members A-D. Siltstone forms a relatively small proportion (about 13%) of Member A but almost half (about 49%) of the whole formation. The beds of siltstone in Member A vary from 0.05-1.10 feet thick, averaging 0.41 feet and having a modal thickness of 0.2 feet. The siltstone units in higher members are much thicker but each may consist of a number of beds. The bedding thicknesses are summarized in Table I.

Member "A" can be divided into two sub-members, the lower about 90 feet thick in which most of the medium and coarse sandstones occur and the higher about 40 feet thick which consists mainly of fine sandstone with some siltstone. The lower sub-member, and especially the lowest 35 feet of it (Units 1-19) in which the medium and coarse sandstone is concentrated, outcrops strongly in the Hobart area, e.g., Porter Hill, Glenorchy, Claremont, Mt. Nassau and Mt. Dromedary, and near New Norfolk, and has drawn the attention of a number of geologists for this reason (e.g., Brill 1956, Banks and Hale 1957, McDougall 1959, Woolley 1959). It outcrops somewhat similarly to the Risdon Sandstone, with low scarps backed by a bench. This sub-member conformably overlies the Grange Mudstone on the Sky Farm Road at Claremont (323092) and probably in the type area.

A sandstone from near the base of this member was briefly described by Banks and Hale (1957, p. 59). In connection with the present study, thin sections of the numbered specimens referred to in the detailed section above were examined using magnifications 24, 75, 340, and 750. Percentages were estimated by visual comparison with charts (Terry and Chillingar, 1955), the roundness of grains estimated by comparison with those figured on A.G.I. Data Sheet 7 (Geotimes, vol. III, No. 1) and sphericities by comparison with silhouettes

**Table I**

*Relationship of Bedding Thickness to Grainsize in Malbina Siltstone and Sandstone.*

| | Member A. | | | | Whole Formation. | |
|---|---|---|---|---|---|---|
| | Total Thickness | No. of Beds | Limits of Thickness of Beds | Av. Thickness | Modal Thickness | Total Thickness | Av. Thickness |
| Coarse Sandstone | 9.71 | 10 | 0.10 - 2.60 | 0.97 | .... | 14.71 | 1.34 |
| Medium Sandstone | 29.40 | 22 | 0.20 - 2.30 | 1.34 | 1.0 (members A + B) | 34.80 | 1.20 |
| Fine Sandstone | 60.70 | 51 | 0.10 - 4.40 | 1.19 | 0.5 (members A — D incl.) | 88.30 | .... |
| Siltstone | 17.15 | 42 | 0.05 - 1.10 | 0.41 | 0.2 (member A only) | 150.35 | .... |

All figures quoted in feet.

shown by Krumbein and Sloss (1951, p. 81, f. 4-9). Grainsize was measured by micrometer ocular and referred to the Wentworth grade scale. The results of the examination of the thin sections are summarized in Table II (Appendix B).

The rocks all have a disrupted framework with phenoclasts in an abundant to predominant matrix. The main component of the phenoclasts is quartz. The quartz includes varieties with undulose extinction, lines of gas bubbles, inclusions of rutile, secondary regrowth, inclusions of crystallised zircon, inclusions of rounded zircon and some with inclusions of microcline. Rock fragments, mainly schist and quartzite but with some igneous rocks, are generally more abundant than feldspar phenoclasts. These latter include orthoclase, microcline, microperthite and soda-rich plagioclase. Muscovite occurs as detrital flakes in some of the sandstone but is only a minor constituent. Fossil fragments form a small proportion of several specimens. Opaque minerals are present in all sections and include ilmenite, magnetite and probably carbonaceous matter. Accessory minerals include euhedral and also rounded zircon, rutile and both brown and green tourmaline. In the stratigraphically higher sandstones the matrix is predominantly a mosaic of granular quartz with small flakes of muscovite and some limonite grains. Lower in the section nontronite (?) is an important component and in the basal 11 feet the mineral assemblage in the matrix is dominated by prehnite and calcite with quartz, nontronite and grossularite forming minor constituents. This assemblage is presumably due to contact metamorphism of the calcareous sandstones and a dolerite sill occurs less than 100 feet stratigraphically below the base of the formation in Jarvis Creek. This sill is, however, less than a foot thick. The composition of the phenoclasts indicates an ultimate source area with low and high grade metamorphic rocks, granites, quartz veins, aplites and volcanic rocks, a source area which was, however, predominantly siliceous. The composition of the matrix of the upper sandstones is in keeping with such a source area. Some reconstitution of the matrix of the higher sandstones is suggested by the occurrence of rims of very small flakes of muscovite around some quartz phenoclasts and the moulding of quartz in phenoclasts onto small flakes of muscovite which also project into the matrix. The authigenic reconstitution of the matrix of all the rocks examined has produced a rock with negligible permeability.

The texture of these rocks is characterised by the large range in grainsize of the phenoclasts which occur in from seven to 14 Wentworth grades. The rocks may thus be referred to as poorly to very poorly sorted. Examination of the thin sections gives the impression that in any one rock type the distribution is skewed towards the finer grades. Most of the phenoclasts are very angular or angular and have a high sphericity. In most of the thin sections examined only 2 or 3 per cent of the grains have sphericities less than 0.3 and over 75 per cent have sphericities over 0.7. In two of the lower sandstones there are patches in which the phenoclasts are separated by little if any matrix but the great majority of the material examined showed a disrupted framework with the phenoclasts well separated by matrix.

The structure of the rocks is best seen in polished sections. A common feature is the presence of stringers of darker material containing more matrix or more carbonaceous matter than the rest of the rock. These stringers are from a fraction of a millimetre to about three millimetres thick, have ill-defined boundaries both in hand specimen and thin section, are irregular in longitudinal and cross-section in that they are rarely straight for more than a few millimetres and some completely enclose ovoid or tear-drop shaped patches of coarser material and they branch and are discontinuous along their length. The stringers are roughly parallel to the bedding. In three specimens some of the stringers are very thin and so arranged as to suggest festoon cross-bedding. One specimen (1145) consists of a section across two sedimentation units totalling eight inches thick. At the base is sandstone with a few medium pebbles and almost free of stringers. A little higher is a zone in which stringers are more common and the grainsize somewhat smaller. Near the top of the first unit is a zone of light grey siltstone. This is followed upwards by sandstone with very fine pebbles then at the top light grey siltstone with stringers suggesting festoon cross-bedding. In both sedimentation units the zone of admixture includes vertical structures delineated by stringers and in the top unit a "Y"-shaped structure in sand defined by light grey siltstone which is probably a piercement structure produced by load (i.e., a flame structure). This specimen shows graded bedding in two poorly-sorted units and the texture and structure are best explained by deposition from turbidity currents.

The sediments examined in thin section all belong to the greywacke suite on textural and structural grounds and could be referred to as sub-labile greywackes (Packham, 1954) or more specifically as lithic and feldspatho-lithic sub-labile arenites (Crook, 1960).

Fossils are present but not abundant. They tend to be concentrated at the base of the sandstone units or associated with pebble bands above bedding planes within the sandstone units. The dominant fossil types in the sandstones are spiriferids ,including *Ingelarella*, but gastropods and fenestellids are also present. Many of the fossils appear to be fragmentary and some of the spiriferids have become disarticulated. Fossils are more common in the lower part of Member A than in the higher part. Fenestellids occur rarely in the sandstone units and somewhat more commonly in siltstones at the top of graded units and in siltstones interbedded with the sandstone. Some fragments which may have been plants occur near the top of the member (unit 90) associated with spiriferids.

The rock fragments which form up to 5% of the rock, are concentrated in the sandstone beds but occur rarely in the siltstones. Most of the rock fragments are rounded or sub-rounded and less than two cms. long. The longest rock fragment seen in this section was about 18 cms. long. The main fragments are of quartz and quartzite but phyllite, slate, vein quartz, quartz-mica schist, quartz feldspar porphyry, siltstone, shale and clay also occur. It is notable that many of the sandstone bands especially those near the base contain no "erratics" within the area examined in detail.

The pebbles in most beds show no obvious preferred orientation but in unit 97 some of the pebbles stand on end. Graded bedding was identified in the field in a number of units, e.g., 3, 13, 43, 53, 62, 73, 76, and suspected in others, e.g., 1.

The siltstones in some units are laminated and carbonaceous and in unit 2 contain pyrite, indicating deposition in quiet, somewhat stagnant, water. Some siltstones contain fenestellids.

From adjacent areas *Strophalosia typica, Grantonia, Neospirifer, Dielasma* and pectinaceans have been reported (McDougall, 1959, p. 62; Woolley, 1959, pp. 99-101) from the basal member.

### Member B

The second member ("B"), 85 feet in thickness, consists predominantly of fissile and non-fissile siltstone with eight beds of medium or fine sandstone varying from 0.1 to 4.60 feet in thickness. Bedding is difficult to identify in the siltstones. Pebbles are uncommon except in unit 107 where they reach a length of 5 cms. No fossils were seen in the siltsstone but occur in the sandstones where they are associated with pebbles. The fossils noted are spiriferids, especially *Ingelarella*. Most of the sandstones are poorly sorted and unit 113 is clearly graded. The pebbles in unit 121 have long axes orientated sub-horizontally. The range of pebble types is similar to that in Member "A". The siltstones consist essentially of quartz with some feldspar, chlorite and mica flakes as well as very small rock fragments. Sorting which appears to be fairly good in hand specimen, is shown by thin-sections to be poor (Banks and Hale, 1957, p. 59). Fissile siltstones become more common near the top of the member. A detailed section through the member is shown as Appendix C.

### Member C

Member "C", five feet thick, consists of very pebbly sandstone which is almost a conglomerate and is very similar in lithology to the basal part of the Risdon Sandstone. In addition to lithological similarity to the Risdon Sandstone, the member shows similarity in type of weathering, outcropping boldly as a low cliff backed by a narrow bench. It could easily be mistaken in field mapping for the Risdon Sandstone but it has no richly fossiliferous member below it as has the Risdon Sandstone. The lower contact has irregularities up to an inch or two in depth but no current direction could be deduced from the irregularities The pebbles which consist mainly of quartz and quartzite, are fairly well rounded and with the exception of a quartzite block over 30 cms. long are less than 10 cms. long. The matrix consists of particles of quartz and a small amount of feldspar of coarse sand grade.

### Member D

The next member, "D", consists of 55 feet of fissile siltstone with some non-fissile bands. In hand specimen the siltstones appear to be fairly well sorted and composed mainly of quartz. Fossils and pebbles were not observed in this member.

### Member E

The top member, "E", consists of 25 to 27 feet of fossiliferous fine-grained sandstone and siltstone. Fossils, which are not common near the base where spiriferids do occur, become very abundant in the top 10 to 11 feet and lenses of dark grey, foetid limestone occur on this level (Banks and Hale, 1957, pp. 59-60). Pebbles of quartz up to 2.5 cms. long were observed in this member; the sandstones are well-sorted and consist of poorly rounded particles of high sphericity. The rocks are compact and brittle or tough. The fossils in this member are spiriferids, including *Ingelarella, Strophalosia ovalis, Terrakea,* fenestellids, *Stenopora, Peruvispira* and a pectinacean. The bivalves are commonly complete, the spinose brachiopods still have spines attached to the shells, some of which are in growth position, and several funnel-shaped fenestellid colonies were observed to be complete and in growth position. On the whole the assemblage is biocoenotic in this member in contrast to the probably thanatocoenotic faunal assemblages in the other members. In adjacent areas this member contains *Strophalosia ovalis, Terrakea solida,* long-hinged spiriferids, fenestellids and pelecypods (McDougall, 1959, p. 62), *Protoretepora ampla* (Woolley, 1959, p. 100), *Ingelarella* ("*Martiniopsis*") and *Stenopora crinita* (Banks and Hale, 1957, p. 59).

## CORRELATION

The Malbina Siltstone and Sandstone occurs widely in Tasmania and may be provisionally identified at Firewood Siding (south of Zeehan), in the north-west coastal area, at Coles Bay, Maria Island and at Mount La Perouse. Some facies variations ocur within Tasmania but cannot yet be fully assessed. Even in areas close to the type section, e.g., New Norfolk, the succession seems to be somewhat different from that in the type section (Woolley, 1959) but the stratigraphy is not so well known.

Voisey (1938, p. 326) recorded "*Spirifer*" *vespertilio,* "*Martiniopsis*" *oviformis,* "*M*" *subradiata,* "*Platyschisma*" *oculus, Astartila* and *Hyolithes* from this formation on the shore-platform at Lindisfarne where Member "A" is exposed. From Eaglehawk Neck he recorded *Fenestella fossula, F. internata* and *Stenopora crinita.* The richly fossiliferous beds at Eaglehawk Neck occur near the Blowhole or just north of the northern headland of Pirates Bay but in both places are above a coarse sandstone correlated on lithological grounds and place in the succession with member "C". The record of *S. crinita* was confirmed by Crockford (1951) who correlated the beds at Eaglehawk Neck with the Mulbring Sub-group in New South Wales. The occurrence of *Strophalosia typica* in the lower part of the Malbina Siltstone and Sandstone suggests correlation with some part of the Branxton Sub-group of New South Wales (Upper Artinskian-Lower Kungurian) and the Ingelara Beds of Queensland. The presence of *Strophalosia ovalis* in the uppermost member suggests correlation with the Mantuan Productus Bed in Queensland (Maxwell, 1954).

## CONDITIONS OF DEPOSITION

The sources of the clastic material in this formation have been considered by Banks and Hale (1957, p. 60) to have been predominantly metamorphic rocks like the Precambrian rocks of Tasmania but some older sediments, granitic and pegmatitic rocks were included in the provenance. Observations in the type section give further evidence of these sources and also suggest some old volcanic rocks in the provenance.

All previous authors have postulated that the numerous "erratics" in the Malbina Siltstone and Sandstone were dropped from icebergs into marine sediments and that the abundance of them relative to that in the underlying formations indicated an increase in the intensity of glaciation. Observations in the type section did not reveal any abundance of undoubted erratics. The pebbles tend to be concentrated in bands and in a few cases show preferred orientation parallel to the bedding. Only in Unit 97 were pebbles seen to be standing on end. Unfortunately, exposure of this unit did not allow observation of broken laminae, indicative of dropped pebbles. Green (1961, p. 20) does, however, record one undoubted erratic in this formation on the shoreline west of Mount Mather. This erratic is elongated and orientated with the long axis almost vertical and clearly breaks the laminations of the siltstone enclosing it. Most of the pebbles in the type section are sub-angular to sub-rounded and no clear examples of faceted pebbles were observed.

Graded bedding was observed in a number of units. The graded beds are poorly sorted. It is noticeable also that in the sandstones the fossils tend to be large but fragmentary and associated with the pebble bands. The siltstones are better sorted than the sandstones. Some siltstones are laminated, most are carbonaceous and one pyritic, thus indicating deposition under quiet conditions with reducing conditions during deposition. Conditions were, however, favourable at times for growth of fenestellids in the silty environment.

The reconstruction which accounts most satisfactorily for observations made to date, is that of a relatively deep sea floor on which silt transported by slow currents from some distant source was being deposited while melting of comparatively rare icebergs contributed a few dropped pebbles to the sediment. In a shallower area gravel, coarse, medium and fine sands were being deposited and heavy-shelled spiriferids, pelecypods and gastropods were living. From time to time instability in the shallower area initiated turbidity currents which picked up the sediments and animals and after carrying them some tens of miles spread them as thin beds over the silts autochthonous to the Hobart area. This reconstruction suggests deposition in the outer iceberg zone of a wet-base glacier (Carey and Ahmad, 1961) but the occurrence of thick-shelled brachiopods in the turbidity current deposits near the base is anomalous if this interpretation is correct.

The change from the fine-grained richly fossiliferous sediments of the Grange Mudstone to the coarse, relatively unfossiliferous rocks of the Malbina Formation may be explained in terms of increasing frequency of turbidity currents. Green (1961) remarked on the occurrence of beds of coarse-grained sandstone as an increasingly important component in the upper part of the Grange Mudstone at Cape Deslacs. The boundary between the two formations may well be considered as occurring above the topmost cream-coloured, calcareous, richly-fossiliferous siltstone of the Grange type and below the lowest poorly-fossiliferous, grey, non-calcareous siltstone of the Malbina type. It is suggested that the change in faunal content does not necessarily reflect a significant change in physical or chemical conditions at the site of deposition but can well be explained as due to the mass killing of the benthonic fauna by suffocation under the sediments deposited by turbidity currents, the frequency of occurrence of which was too high to allow recolonisation of the area from parts of the sea-floor unaffected by these currents.

The increase in the sandstone and pebble content of the sediments from the Grange Mudstone into the Malbina Formation is thus not directly due to increasing intensity of glaciation but to greater instability in a source area probably in north-western, western, or south-western Tasmania (Banks and Hale, 1957, p. 62) or beyond the present confines of Tasmania in those directions. The causes of the instability may have been climatic or tectonic and it is perhaps significant that similar rocks occur at about the same time in New South Wales and that orogenic movements are postulated in the Hunter River area of New South Wales at about this time (Browne, 1950, Vol. 1, p. 386). Dropped pebbles occur in the Hobart area in the Berriedale Limestone (quarries near Collinsvale) as shown by orientation of the pebbles and breaking of laminae. There does not seem to be any significant difference in the abundance of such pebbles in the upper part of the Cascades Group from that in the Malbina Formation. Thus there is no clear evidence of an increase in intensity of glaciation at this level as postulated by Lewis (1937) and later authors.

Member "C" and the Risdon Sandstone are also thought to be turbidity current deposits but more detailed work will have to be done to establish this. If they are, they again reflect instability in the source area.

The topmost member of the formation shows a return of abundant life to the area, and it is probably significant that this occurs after the longest interval of uninterrupted silt deposition in the area. Quiet conditions prevailed during deposition of the member and the faunal assemblage is dominantly biocoenotic. The dominant organism in this assemblage varies from place to place within Tasmania—*Strophalosia, Terrakea,* spiriferids, fenstellids and pelecypods or gastropods being the dominant forms in different places. Such variation would be expected if the faunas were biocoenotic. Local marine life was again destroyed by the widespread deposition of the Risdon Sandstone and reappeared only fitfully during deposition of the Ferntree Mudstone.

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## Appendix A

### *Detailed Stratigraphy of Member A.*

Top:—

*Unit* 102.
1.0 feet.—Fine sandstone—fissile—with a few small pebbles.

*Unit* 101.
0.6 feet.—Medium sandstone—similar to unit 100 but this unit is fissile.

*Unit* 100.
1.0 feet—Medium sandstone—very pebbly with pebbles of quartzite and slate up to 4 cms. in length—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 99.
0.8 feet.—Siltstone—top three inches fissile—pebbles up to 1.5 cms. long.

*Unit* 98.
1.25 feet.—Fine sandstone—quartzite pebbles up to 2 cms. in length—fissile—spiriferids near the base.

*Unit* 97.
0.55 feet.—Fine sandstone—pebbles up to 8 cms. in length—some pebbles in this bed standing on end—top of this bed fissile in places.

*Unit* 96.
1.0 feet.—Fine sandstone—similar to unit 93.

*Unit* 95.
0.05 feet.—Fissile siltstone.

*Unit* 94.
0.4 feet.—Fine sandstone—similar to unit 92—pebbles up to 0.5 cms.

*Unit* 93.
0.15 feet.—Fine sandstone—sorting good, sphericity high, roundness low—fissile.

*Unit* 92.
0.75 feet.—Fine sandstone—dominantly quartz and some feldspar—quartz pebbles up to 2 cms. in length—properties similar to unit 90 but with no fossils.

*Unit* 91.
0.1 feet.—Fissile siltstone with some pebbles.

*Unit* 90.
0.7 feet.—Fine sandstone—quartz—sorting poor, sphericity fair to high, roundness low—fragments of phyllite up to 5 cms. in length—fragments of spiriferids and ? plant fragments.

*Unit* 89.
0.4 feet.—Sandstone and siltstone—medium sandstone with a clay matrix—quartzite pebbles up to 2 cms. in length—most pebbles well rounded—top three-quarters of an inch of the unit fissile siltstone.

*Unit* 88.
0.9 feet.—Sandstone and siltstone—basal two and a half inches medium sandstone containing pebbles up to 2.5 cms. in length—overlain by 4 inches of laminated, non-fissile siltstone—overlain by 4 inches of fissile, laminated siltstone—medium grey.

*Unit* 87.
0.4 feet.—Fissile siltstone—similar to unit 77.

*Unit* 86.
1.05 feet.—Fine sandstone—similar to unit 78—pebbles up to 1 cm. at base of unit.

*Unit* 85.
0.65 feet.—Fine sandstone—quartz present—no fossils—sorting good, sphericity high, roundness low—compact and mostly non-fissile although the top 2 inches are fissile and with an increase in silt size material.

*Unit* 84.
2.8 feet.—Fine sandstone—pebbles of slate, quartzite and quartz—feldspar porphyry—pebbles up to 4 cms. in length—specimen 1150.

*Unit* 83.
0.35 feet.—Fissile siltstone—similar to unit 77.

*Unit* 82.
2.65 feet.—Fine sandstone—few pebbles up to 1.25 cms. in length—partings at 2, 5, 13, and 23 inches above the base.

*Unit* 81.
0.45 feet.—Fissile siltstone—similar to unit 77.

*Unit* 80.
2.6 feet.—Fine sandstone—similar to unit 78—parting 7 inches above the base.

*Unit* 79.
0.35 feet.—Fissile siltstone—similar to unit 77.

*Unit* 78.
3.0 feet.—Fine sandstone—about 40 to 50 per cent quartz—matrix not seen—rock fragments not seen—no fossils—sorting good, sphericity fairly high, roundness low—compact, brittle, non-fissile.

*Unit* 77.
0.2 feet.—Fissile siltstone—light bluish grey—sorting good—other properties not obvious.

*Unit* 76.
1.75 feet.—Medium sandstone at base with numerous pebbles of quartzite—grades into a fine sandstone at approximately 0.6 feet above the base.

*Unit* 75.
0.1 feet.—Fissile siltstone—similar to unit 72.

*Unit* 74.
0.25 feet.—Fine sandstone—similar to base of unit 73.

*Unit* 73.
0.75 feet.—Fine sandstone—similar properties to unit 71 but grades into a fissile siltstone in the top 0.1 feet.

*Unit* 72.
0.2 feet.—Siltstone—fissile—sorting good.

*Unit* 71.
1.0 feet.—Fine sandstone—quartz—matrix not obvious—rock fragments not obvious—no fossils—sorting good, sphericity high, roundness low—compact, brittle, tough.

*Unit* 70.
0.4 feet.—Laminated non-fissile siltstone—sorting good—compact, brittle.

*Unit* 69.
2.7 feet.—Fine sandstone—quartz and some feldspar—matrix not seen—rock fragments of quartzite at base and at 2.24 feet above base—one pebble measured 10 cms. in length—no fossils seen—sorting fair, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 68.
0.8 feet.—Siltstone—laminated—fissile—sorting good.

*Unit* 67.
1.5 feet.—Fine sandstone—properties similar to unit 65.

*Unit* 66.
0.4 feet.—Coarse sandstone—dominantly quartz with a little feldspar—clay matrix—no fossils—no rock fragments seen—some of the quartz fragments up to 3 mm.—sorting poor, sphericity high, roundness poor—compact, brittle, non-fissile.

*Unit* 65.
0.65 feet.—Fine sandstone—sorting good, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 64.
3.0 feet.—Fine sandstone—quartz with coarse grade quartz fragments which are very angular—pebbles in band at base up to 8 cms. in length—patch of pebbles 7 inches from top of unit with a parting under it.

*Unit* 63.
0.35 feet.—Siltstone—fissile—similar properties to unit 61.

*Unit* 62.
2.5 feet.—Sandstone and siltstone—40 per cent quartz, some feldspar—rock fragments rare but in the top part of the unit occurred one piece of slate 18 cms. by about 2.5 cms.—fossils include *Ingelarella* and other spiriferids in a band 1 inch thick about 9 inches above the base of the unit—fossils not oriented—sorting poor, sphericity high, roundness low—at the base is a graded layer, overlying this is another graded layer (1.9 feet thick) and then at the top another graded layer—sandstone grades from coarse grade to a siltstone—compact, brittle, non-fissile—white to light bluish grey—specimen 1149.

*Unit* 61.
0.3 feet.—Siltstone—sorting good—fissile bedding plane between this unit and overlying unit 62 is irregular.

*Unit* 60.
1.0 feet.—Fine sandstone with few fossils—similar to unit 58.

*Unit* 59.
0.1 feet.—Fissile siltstone—similar to unit 55 but without carbonaceous markings.

*Unit* 58.
0.4 feet.—Fine sandstone—quartz about 40 to 50 per cent—rare fragments of phyllite up to 5 mm. long—rare fossils (spiriferids)—sorting poor, sphericity fairly high, roundness low—compact, brittle, non-fissile—light bluish grey with white patches—specimen 1148.

*Unit* 57.
0.4 feet.—Siltstone and sandstone—consists of two fissile siltstone units and a fine sandstone between them.

*Unit* 56.
0.8 feet.—Fine to medium sandstone—about 40 per cent quartz—coarser at base than at top of unit—about 5 per cent of pebbles—some up to 2 cms.—no fossils—clay matrix (high percentage)—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile—light bluish grey and weathers to greyish orange—specimen 1147 is specimen of coarser part of this bed.

*Unit* 55.
0.4 feet.—Siltstone—most properties not obvious—sorting appears to be fair—fissile—carbonaceous markings—light grey.

*Unit* 54.
8.2 feet.—Medium to coarse sandstone—quartz and feldspar in about equal proportion—fossils are elongate fibres (possibly sponge spicules)—sorting fair, sphericity high, roundness low—light grey—compact, brittle, non-fissile—contains pebbles of quartz, quartzite, vein-quartz, quartz-mica schist and siltstone—pebbles occur in bands at 2.2 feet above base, 3.4 feet above base, 4.2 feet above base, 5.5 feet above base, 7.3 feet above base—pebble bands at 2.2 feet and 4.2 feet are thick—about 4 inches—specimen 1146.

*Unit* 53.
0.7 feet.—Graded sandstone and siltstone—basal inch consists of a coarse quartz sandstone with clay fragments up to 1 cm. in diameter—this grades upward into a laminated siltstone at the top which is the same as unit 52—specimen 1145.

*Unit* 52.
0.9 feet.—Laminated siltstone—most properties not visible—sorting appears to be good—bedding is very thin—down to less than a millimetre—contains lenses of a white fine-grained material in a grey matrix—may be cross-bedded—compact, brittle, non-fissile—light bluish grey with white lenses—specimen 1144.

*Unit* 51.
2.3 feet.—Fine sandstone—quartz—quartz fragments coarser at base than at top—fragments abundant—no fossils—sorting poor, sphericity mediu mto high, roundness low—compact, brittle, massive—light grey blue.
11.4 feet.—No outcrop.

*Unit* 50.
1.1 feet.—Siltstone—fine-grained—most properties not obvious—fissile—grey-green.

*Unit* 49.
0.4 feet.—Fine sandstone—similar to unit 39.

*Unit* 48.
0.2 feet.—Siltstone—similar to unit 42.

*Unit* 47.
1.05 feet.—Medium sandstone—quartz—sorting, middling, sphericity high, roundness, low—compact, brittle, non-fissile.

*Unit* 46.
0.15 feet.—Siltstone—similar to unit 42.

*Unit* 45.
0.8 feet.—Fine sandstone—similar to unit 39.

*Unit* 44.
0.1 feet.—Siltstone—similar to unit 42.

*Unit* 43.
1.2 feet.—Medium sandstone—slightly coarser at base with 0.6 cms. long quartz fragments and rock fragments—at the top becomes a fine sandstone with some small quartz fragments—this may represent grading—sorting from middling at top to poor at base—sphericity fairly high and roundness low—compact, brittle, non-fissile.

*Unit* 42.
0.10 feet.—Siltstone—sorting middling—compact, non-fissile.

*Unit* 41.
0.45 feet.—Fine sandstone—similar properties to unit 39.

*Unit* 40.
0.15 feet.—Fissile siltstone—similiar properties to unit 28.

*Unit* 39.
1.2 feet.—Fine sandstone—quartz—sorting middling, sphericity medium, roundness low—compact, brittle, non-fissile.

*Unit* 38.
0.4 feet.—Siltstone—laminated—fissile, colour blue grey.

*Unit* 37.
2.3 feet.—Medium sandstone—quartz—few quartz particles and small rock fragments up to 0.3 cms.—clay matrix—sorting middling, sphericity high, roundness low—compact, non-fissile.

*Unit* 36.
0.5 feet.—Fine sandstone—fissile—similar to unit 34.

*Unit* 35.
2.0 feet.—Fine sandstone—quartz and a little feldspar—no rock fragments—no fossils—matrix not visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 34.
0.5 feet.—Fine sandstone—similar properties to unit 31 except this unit is fissile.

*Unit* 33.
0.7 feet.—Fine sandstone—similar properties to unit 31.

*Unit* 32.
0.6 feet.—Fissile siltstone—similar properties to unit 28.

*Unit* 31.
0.7 feet.—Fine sandstone—quartz—no rock fragments—no fossils—matrix not visible—sorting good, sphericty medium, roundness low—compact, fairly brittle, non-fissile.

*Unit* 30.
0.3 feet.—Fissile siltstone—similar properties to unit 28.

*Unit* 29.
4.4 feet.—Fine sandstone—quartz and rare particles of feldspar pebbles of vein quartz—matrix siliceous—compact, brittle, tough.

*Unit* 28.
0.6 feet.—Fissile siltstone—blue grey colour, most properties not visible.

*Unit* 27.
3.1 feet.—Fine sandstone—quartz, some feldspar—shale pebbles—matrix not visible—no fossils—sorting middling, sphericity high, roundness low—compact, brittle, tough.

*Unit* 26.
0.1 feet.—Fissile siltstone—olive grey colour—matrix not visible—no rock particles or fossils.

*Unit* 25.
1.5 feet.—Medium sandstone—quartz—clay matrix—at base small lenses of coarse grained quartz particles and rock fragments up to 0.15 cms.—slate pebbles—a few spiriferids—sorting middling to poor, sphericity medium to fairly high, roundness low—compact, brittle, non-fissile.

*Unit* 24.
0.6 feet.—Fine sandstone—quartz—carbonaceous laminations—matrix not visible—no rock fragments—no fossils—sorting good—sphericity high—roundness low—fissile.

*Unit* 23.
2.2 feet.—Medium sandstone—quartz with some particles up to 1 cm. long—matrix not visible—rock fragments mainly quartzite up to 1.25 cms.—spiriferids—sorting middling to poor, sphericity high, roundness low—compact, brittle, non-fisslie.

*Unit* 22.
1.0 feet.—Siltstone—quartz, some feldspar—rock fragments and fossils not seen—sorting middling to poor—sphericity fairly high, roundness low—compact, brittle, non-fissile—light bluish grey.

*Unit* 21.
1.6 feet.—Fine to medium sandstone—quartz with fragments and rock pebbles up to 0.6 cms. long—matrix siliceous—no fossils—sorting poor, sphericty medium to high, roundness low—light yellow brown.

*Unit* 20.
0.45 feet.—Fissile siltstone—quartz—matrix not obvious—rock particles not obvious—no fossils—sorting good, sphericity high, roundness low—olive grey.

*Unit* 19.
5.1 feet.—Coarse sandstone—quartz and about 10 per cent feldspar—matrix siliceous—pebbles up to 5 cms. in length at the base and rare pebbles and fossils in bands at 1.9 and 4.5 feet above base—sorting poor to middling—sphericity medium to high, roundness low—fossil and pebble bands may indicate the base of beds—compact, brittle, non-fissile.

*Unit* 18.
0.75 feet.—Light blue fissile siltstone—similar to unit 14.

*Unit* 17.
2.05 feet.—Medium sandstone—quartz, some large quartz fragments—matrix partly ferruginous—fossils (about 2 per cent)—spiriferids—sorting good, sphericity high, roundness low—compact, brittle, tough.

*Unit* 16.
0.25 feet.—Fine fissile sandstone—quartz—rock pebbles (quartzite) up to 2.5 cms. long—matrix not visible—no fossils—sorting poor, sphericity high, roundness low—blue grey.

*Unit* 15.
1.8 feet.—Fine sandstone—quartz—some quartz fragments up to 0.3 cms. long—no rock particles visible—matrix not visible—no fossils—bluish grey—grain size is coarser at bottom of unit than at top—may represent grading—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 14.
0.3 feet.—Light blue fissile siltstone—similar properties to unit 12—but in this unit there are no fossils.

*Unit* 13.
2.0 feet.—Fine sandstone with fissile siltstone layers—about 1 inch thick at 0.55 and 1.1 feet above the base—physical properties similar to unit 11—spiriferids occur just above each fissile layer—sandstone layers may show graded bedding into the fissile siltstone.

*Unit* 12.
0.3 feet.—Fissile siltstone—mottled light bluish grey—quartz—sorting middling, sphericity medium to high—roundness low—fossils are fenestellids.

*Unit* 11.
2.7 feet.—Fine sandstone—some quartz fragments up to 0.6 cms. long—quartz dominant mineral, some feldspar—rock particles not visible—matrix partly ferruginous—sorting middling, sphericity high, roundness low—fossils occur in bands—1.3 feet above the base of the unit bryozoans—2.15 beet above base fenestellids and spiriferids—2.6 feet above base spiriferids and gastropods—yellowish grey.

*Unit* 10.
0.6 feet.—Alternating fine sandstone and siltstone—quartz and feldspar—sorting middling, sphericity high, roundness low—rare calcareous fossils—rock particles not visible—compact, brittle, tough.

*Unit* 9.
3.1 feet.—Medium to coarse fossiliferous sandstone—properties the same as unit 7 but with fewer fossils—one pebble of quartzite over 8 cms. long.

*Unit* 8.
0.4 feet.—Alternating fine sandstone and siltstone—quartz and feldspar present—sorting middling, sphericity high, roundness low—rock particles not visible—compact, brittle, tough—contains some calcareous fossils—specimen 1143.

*Unit* 7.
3.6 feet.—Medium to coarse fossiliferous sandstone—70 per cent quartz, 10 per cent feldspar and 10 per cent calcareous shells—approximately 1 per cent rock particles—mainly quartzite up to 5 cms. in length—up to 10 per cent fossils—mainly spiriferids which occur in bands—10 per cent of partly ferruginous matrix—sorting middling to good, sphericity high, roundness low—bedding units about 7 inches thick—base of beds determined by coarser pebble concentrations—top 9 inches highly fossiliferous with abundant fenestellids—compact, brittle, non-fissile—light grey—specimen 1142.

*Unit* 6.
0.25 feet.—Fine sandstone—quartz and about 15 per cent feldspar—rock particles not visible—a few spiriferids—matrix partly ferruginous—sorting middling, sphericity is greater than 0.8, roundness less than 0.3—compact, brittle and non-fissile—yellowish grey.

*Unit* 5.
1.2 feet.—alternating fine sandstone with finely-laminated dark grey siltstone (¼-inch units)—sandstone of quartz and feldspar with beds up to 2 inches thick—sorting middling, sphericity high, roundness low—compact, brittle, tough—yellowish grey—specimen 1141.

*Unit* 4.
1.8 feet.—Medium sandstone—60 plus per cent quartz, 20 to 30 per cent feldspar—rock particles not visible—rare *Ingelarella*—clay matrix—bedding plane 1.1 feet above base—sorting middling to good—sphericity greater than 0.8, roundness less than 0.3—compact, brittle—light bluish grey.

*Unit* 3.
1.4 feet.—Medium sandstone—70 plus per cent quartz—rock particles not visible—one bedding plane in centre of unit—ferruginous matrix in lower half and siliceous in top half—top half graded—rare spiriferids and fenestellids right at top of unit in some fissile material—sorting is middling sphericity greater than 0.7, roundness less than 0.3—light bluish grey—mainly unit is compact and brittle—specimen 1140.

*Unit* 2.
1.0 feet.—Siltstone—probably one unit—60 per cent quartz—20 per cent feldspar—pyrite—rock fragments and fossils not obvious—matrix not visible—sorting middling to poor—sphericity between 0.5 and 0.9—roundness less than 0.5—carbonaceous laminations present—compact, brittle, weathered to thin laminations—negligible porosity—light bluish grey.

*Unit* 1.
1.85 feet.—Medium sandstone—some particles in coarse sand grade—graded bedding may be present with fine sand grade at top of bed—80 per cent quartz particles—siliceous matrix—no rock fragments visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile—spiriferids at base and band of fragmentary fossils 13 ins. above base—specimen 1139—yellowish grey.

There is a break of 4.63 feet below the lowest exposure of the Malbina Siltstone and Sandstone and the topmost exposure of the underlying Grange Mudstone.

Specimen numbers refer to specimens in the collection of the University of Tasmania, Geology Department. Grainsizes were measured in the field by comparison under a hand lens of the rock with a standard chart (similar to that illustrated by Chillingar (1956). Colours quoted refer to those listed in Goddard *et al* (1948).

## Appendix B.

# Table II — Tabular Summary of Microscopic Characters of Some Rocks in Member A, Malbina Formation

| No. | COMPOSITION | | | TEXTURE | | | | | | | | | STRUCTURE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PHENOCLASTS (percentages quoted on matrix-free basis) | % MATRIX | MATRIX (percentages quoted on phenoclast-free basis) | PHENOCLASTS | | | | | | | MATRIX | OTHERS | |
| | | | | Grainsize | | | Roundness | | Sphericity | | | | |
| | | | | Maximum | Modal | Minimum | Modal | Range | Modal | Range | | | |
| 1139 (Unit 1) | Quartz .. 85<br>Quartzite, Quartz-schist } 7<br>Plagioclase .. 1<br>Opaque .. 5<br>(Fossils formed about 2% of hand specimen) | 50 | Quartz .. 10<br>Prehnite .. 70<br>Nontronite 15<br>Grossularite 5 | Coarse sand | medium sand | very fine silt | very angular | very angular to sub-angular | 0.9 | 0.1 to 0.9 | Mosaic of quartz grains with laths and plates of prehnite, euhedral crystals of grossularite and plates and spherulites of nontronite | mainly disrupted framework but some patches of mosaic texture of phenoclasts | |
| 1140 (Unit 3 | Quartz .. 85<br>Quartz-schist, Quartzite } 3<br>Fossil Frags. 8 (in hand specimen)<br>Orthoclase .. 1<br>Zircon .. <1<br>Albite .. <1<br>Opaque .. 2 | 60 | Quartz .. 10<br>Prehnite .. 50<br>Nontronite 10<br>Gossularite 10<br>Calcite .. 20 | Coarse sand in thin section but medium pebble in hand specimen | Medium sand | Fine silt | Very angular | Very angular to sub-angular | 0.9 | 0.1 to 0.9 | Order of development—quartz, prehnite, calcite, nontronite, garnet | Mainly disrupted framework but some patches with mosaic texture | Crude bedding seen in thin section with suggestion of flame structure; in hand specimen bedding shown by stringers richer in matrix |
| 1141 (Unit 5) | Quartz .. 90<br>Opaque .. 5<br>Feldspar incl. Andesine, Microcline, Quartz schist, Musc. schist, Quartzite, Graphic granite, Aplite, Chlorite schist .. 2<br>Muscovite < 1<br>Zircon .. < 1 | 40 | Quartz .. 60<br>Muscovite .. 35<br>Limonite .. 5 | Medium sand | Fine sand | Very fine silt | Very angular | Very angular to sub-rounded | 0.7 | 0.1 to 0.9 | Mosaic texture with laths of muscovite with no preferred orientation noticeable | Disrupted framework | Swirl structure shown by stringers of very fine, opaque material; stringers partly limonitic but not entirely so |
| 1142 (Unit 7) | Quartz.. ..92<br>Fossil frags. .. 5<br>Quartzite .. 1<br>Rutile .. < 1<br>Opaque .. 2 | 40 | Calcite .. 30<br>Prehnite .. 28<br>Quartz .. 30<br>Grossularite 8<br>Limonite .. 2<br>Nontronite 2 | Very coarse pebble-sized fossil frags; rock and mineral frags to very fine pebble | Fine sand (30% of rock in modal grade) | Fine silt | Very angular | Very angular to sub-rounded | 0.8 | 0.3 to 0.9 | Mosaic of granular quartz in some areas; large plates of calcite moulding crystallised quartz and with inclusions of quartz and prehnite; otherwise as in 1139 | Disrupted framework; large plates of calcite with inclusions of quartz | Fossil fragments recrystallised |

| No. | COMPOSITION | | | TEXTURE | | | | | | | | STRUCTURE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PHENOCLASTS (percentages quoted on matrix-free basis) | % MATRIX | MATRIX (percentages quoted on phenoclast-free basis) | PHENOCLASTS | | | | | | MATRIX | OTHERS | |
| | | | | Grainsize | | | Roundness | | Sphericity | | | |
| | | | | Maximum | Modal | Minimum | Modal | Range | Modal | Range | | |
| 1143 (Unit 8) | Quartz .. 90<br>Quartz schist<br>Quartz muscovite schist<br>Chlorite rock<br>Quartz-albite rock .. 2<br>Feldspar—<br>Microperthite ..<br>Orthoclase<br>Microcline<br>Acid plag. 1<br>Opaque .. 3<br>Fossil frags. .. 2<br>Rutile .. < 1<br>Zircon .. .. 1 | 75 | Quartz .. 62<br>Calcite .. 10<br>Prehnite .. 7<br>Nontronite 5<br>Limonite .. 1<br>Muscovite .. 15 | Very coarse sand, but in hand spec. quartz grains to very fine pebbles and fossil frags. to coarse pebble | Fine sand | Fine silt | Angular | Very angular to sub-angular | 0.7 | 0.1 to 1.0 | Mainly mosaic of granular quartz with flakes of muscovite and spherulites and plates of nontronite; calcite interstitial moulding laths of prehnite in places; granules of limonite | Disrupted framework | Stringers shown in hand spec.; in thin section stringers marked by opaque material; bedding shown by lines of phenoclasts and changes in grain size |
| 1144 (Unit 52) | Quartz .. 88<br>Quartz schist<br>Quartz musc. schist .. 3<br>Musc. schist<br>Plagioclase (acid) 2<br>Microcline<br>Muscovite .. 3<br>Opaque .. 3<br>Zircon .. < 1<br>Tourmaline < 1 | 35–40 | Quartz .. 70<br>Muscovite .. 20<br>Limonite .. 10 | Coarse sand | Very fine sand (more than 50% in this grade) | Fine silt | Very angular | Very angular to sub-angular | 0.9 | 0.5 to 1.0 | Mainly mosaic of quartz with laths of muscovite, limonitic granules | Disrupted framework | Stringers of dark material in hand specimen appear in places to delineate festoon cross-bedding; contains intertonguing patch of coarser, more disrupted sand |
| 1145 *A, B, C* (Unit 53) | Quartz .. 85<br>Quartz-Microcline rock ..<br>Micaceous quartzite<br>Muscovite schist ..<br>Chlorite<br>Trachytic rock 7 | 60 | Quartz .. 90<br>Muscovite .. 10<br>Nontronite < 1 | *C*— medium pebble | Fine sand | Fine silt | Angular | Very angular to sub-rounded | 0.9 | 0.1 to 0.9 | Mainly mosaic of quartz with laths of muscovite; rim of muscovite around some quartz phenoclasts | Disrupted framework | *C* is at base, *A* towards top of bed; stringers of light grey material in hand spec.; forms two graded beds, bedding shown by preferred orientation of elongate phenoclasts in places and by lines of phenoclasts |
| | | | | *B*— Very coarse sand | Fine sand | Very fine silt | | | | | | Disrupted framework |
| | Muscovite .. 3<br>Microcline<br>Microperthite<br>Acid plagioclase .. 2<br>Zircon .. < 1<br>Tourmaline < 1<br>Rutile .. < 1<br>Opaque .. 2 | 50 | | *A*— Very fine pebble | Very fine or fine sand | Very fine silt | Very angular | Very angular to sub-angular | 0.8 | 0.1 to 0.9 | | Disrupted framework | |

| No. | COMPOSITION | | | TEXTURE | | | | | | | | STRUCTURE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PHENOCLASTS (percentages quoted on matrix-free basis) | % MATRIX | MATRIX (percentages quoted on phenoclast-free basis) | PHENOCLASTS | | | | | | | MATRIX | OTHERS | |
| | | | | Grainsize | | | Roundness | | Sphericity | | | | |
| | | | | Maximum | Modal | Minimum | Modal | Range | Modal | Range | | | |
| 1146 (Unit 54) | Quartz .. 86<br>Muscovite schist .. } 5<br>Musc. quartz schist } 5<br>Quartzite } 5<br>Plagioclase .. 3<br>Muscovite .. 3<br>Opaque, incl. Ilmenite .. 2<br>Tourmaline < 1<br>Zircon .. < 1 | 60 | Quartz .. 68<br>Nontronite 15<br>Muscovite .. 7<br>Limonite .. 10 | Coarse sand | Very fine sand | Very fine silt | Very angular | Very angular to angular | 0.9 | 0.1 to 0.9 | Mosaic of quartz with laths of muscovite, spherulites and plates of nontronite and limonitic granules | Disrupted framework | Bedding shown by concentration of matirx and by limonitic staining body of fine sand oriented almost at right angles to bedding in very fine sand .. |
| 1147 (Unit 56) | Quartz .. 80<br>Muscovite schist .. } 10<br>Quartz mica schist .. } 10<br>Quartzite } 10<br>Muscovite .. 4<br>Feldspar microcline albite .. } 2<br>Tourmaline .. 1<br>Zircon .. < 1<br>Opaque .. 2 | 40 | Quartz .. 60<br>Muscovite .. 38<br>Nontronite 2 | Hand specimen has small cobble; thin section has grains to coarse sand | Very fine sand | Fine silt | Angular | Very angular to subrounded | 0.8 to 0.9 | 0.1 to 1.0 | Mosaic of quartz with laths of muscovite; nontronite as radiating fibres or hexagonal plates | Disrupted framework | |
| 1148 (Unit 58) | Quartz .. 80<br>Muscovite schist .. } 10<br>Quartzite } 10<br>Muscovite quartz schist } 10<br>Muscovite .. 2<br>Opaque .. 2 | | Quartz .. 93<br>Muscovite .. 5<br>Limonite .. 2 | Hand specimen has fine pebbles | | | | | | | Mosaic of quartz grains with laths of muscovite and limonitic granules | | Section shows two portions, *A* very fine sand and *B* fine sand with a bulge from *B* extending into *A* |
| | Tourmaline < 1<br>Zircon .. < 1<br>Feldspar— Plagioclase (acid) Orthoclase Microcline } 5 | 75<br>40 | | *A*— Medium sand | Fine to very fine sand | Very fine silt | Very angular | Very angular to subrounded | 0.9 | 0.1 to 0.9 | | Disrupted framework | |
| | | | | *B*— Very coarse sand | Fine sand | Very fine silt | As *A* | As *A* | 0.8 to 0.9 | 0.3 to 1.0 | | Disrupted framework | |

| No. | COMPOSITION | | | TEXTURE | | | | | | | | STRUCTURE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PHENOCLASTS | % MATRIX | MATRIX | PHENOCLASTS | | | | | | MATRIX | OTHERS | |
| | (percentages quoted on matrix-free basis) | | (percentages quoted on phenoclast-free basis) | Grainsize | | | Roundness | | Sphericity | | | |
| | | | | Maximum | Modal | Minimum | Modal | Range | Modal | Range | | |
| 1149 (Unit 62) | Quartz .. 88<br>Muscovite schist ..<br>Quartz mica chist ..<br>Micaceous quartzite<br>Quartzite } 7<br>Opaque .. 2<br>Tourmaline < 1<br>Zircon .. < 1<br>Feldspar—<br>microcline<br>Acid plagioclase } 2 | 40 | Quartz .. 95<br>Muscovite .. 5 | Hand specimen has wood fragment of fine pebble size; very fine pebble in slide | Very fine sand | Very fine silt | Angular to very angular | Very angular to sub-rounded | 0.9 | 0.1 to 0.9 | Mosaic of quartz grains and muscovite flakes | Disrupted framework | Bedding shown by areas richer in matrix than others, by lines of limonitic material and by some preferred orientation of elongate fragments |
| 1150 (Unit 84) | Quartz .. 84<br>Musc. quartz schist ..<br>Trachytic rock ..<br>Quartzite<br>Sheared quartzite<br>Musc.-haematite rock } 10<br>Quartz-feldspar porphyry, black slate in hand specimen)<br>Muscovite .. 1<br>Tourmaline < 1<br>Zircon .. < 1<br>Feldspar—&<br>Acid plagioclase<br>Microperthite ..<br>Orthoclase } 2<br>Opaque .. 2 | 60 | Quartz .. 94<br>Muscovite .. 3<br>Limonite .. 3 | Hand specimen has coarse pebbles | Very fine sand with patches of fine sand | Very fine silt | Very angular or angular | Very angular to sub-rounded | 0.9 | 0.1 to 0.9 | Mosaic of quartz grains and muscovite flakes, and, in places, limonitic granules; some quartz phenoclasts rimmed by fine muscovite flakes; some quartz phenoclasts appear moulded onto muscovite flakes | Disrupted framework | Pebbles occur in patch in one specimen; very fine cross-bedding may be present; bedding in section shown by lines of coarser grains with less matrix and preferred orientation of elongate fragments |

## Appendix C

### *Detailed Stratigraphy of Member B.*

Top:—

*Unit* 124.
12.6 feet.—Fissile and non-fissile siltstone—similar in properties to unit 110.

*Unit* 123.
4.6 feet.—Fine to medium sandstone—pebbles up to 4 cms. in length—pebbles of quartz and quartz feldspar porphyry.

*Unit* 122.
10.6 feet.—Fissile siltstone—similar to unit 110.

*Unit* 121.
0.9 feet.—Medium sandstone—rounded pebbles up to 5 cms. long near base—pebbles of quartz, quartzite, phyllite—long axes of pebbles are sub-horizontal.

*Unit* 120.
5.2 feet.—Fissile siltstone—similar to unit 110.

*Unit* 119.
0.1 feet.—Fine sandstone with a few rounded pebbles.

*Unit* 118.
5.2 feet.—Fissile siltstone—similar to unit 110.

*Unit* 117.
0.3 feet.—Medium sandstone—fossils are rare, *Ingelarella*, and rare small pebbles.

*Unit* 116.
18.15 feet.—Fissile siltstone—similar to unit 110.

*Unit* 115.
0.25 feet.—Fine to medium sandstone sorting fair to good, sphericity high, roundness low—compact, brittle, tough.

*Unit* 114.
1.6 feet.—Fissile siltstone—similar to unit 110.

*Unit* 113.
0.3 feet.—Medium sandstone—graded bedding—very poorly sorted, sphericity high, roundness low—pebbles up to 2.5 cms. in length.

*Unit* 112.
1.95 feet.—Fissile siltstone—similar to unit 110.

*Unit* 111.
0.25 feet.—Medium sandstone—rare fossils (spiriferids)—pebbles up to 2.5 cms. in length—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

*Unit* 110.
3.1 feet.—Siltstone—sorting good—fissile.

*Unit* 109.
1.1 feet.—Medium sandstone—quartz—sorting poor, sphericity high, roundness low—matrix not visible—contains quartzite pebbles up to 5 cms. in length—no fossils—compact, brittle, non-fissile.

*Unit* 108.
1.9 feet.—Siltstone—sorting good—no pebbles visible—fissile.

*Unit* 107.
9.0 feet.—Siltstone—sorting fair to poor—abundant pebbles—mostly quartzite—some up to 5 cms. in length—fissile.

*Unit* 106.
3.0 feet.—Siltstone—sorting good—compact, brittle, massive—light grey—partings at 1.5 and 2.4 feet above base.

*Unit* 105.
1.6 feet.—Siltstone—sorting poor—contains abundant sand grade quartz fragments—non-fissile—light grey.

*Unit* 104.
1.6 feet.—Siltstone—sorting middling to poor—pebbles (well rounded) up to 2.5 cms. in length—contains sandy lenses of quartz particles.

*Unit* 103.
2.0 feet.—Siltsone—most properties not visible—sorting appears to be good—contains rare pebbles up to 0.1 inches in length—compact, brittle, non-fissile—light grey.

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# THE OLD PSYCHOLOGY*

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The spate of "new" psychologies with which we were familiar in the nineteen-twenties (to say nothing of the nineteen-tens and the eighteen-nineties) has died down, and psychologists now talk in terms of points of view and preferred concepts rather than party allegiances. Nevertheless, one impression persists which needs to be enquired into. Among those interested in the subject, but not themselves psychologists, it takes this form: psychology is in continuous, large scale flux, and is therefore a new-fangled, insecure, aggressive, and rather "gimmicky" field of endeavour. Among psychologists themselves, the assumption is more specific and sophisticated: it is, that psychology became respectable with the rise of experimentalism (with the foundation by Wilhelm Wundt of the laboratory at Leipzig in 1879, if an exact date is wanted), and that previous work can be relegated to a species of antiquarian rag-bag, or rubbish-heap of superstition.

True, any standard history will show that this is by no means correct, and when a psychologist directs his attention specifically to the history of his specialty within the subject, he keeps finding anticipations of concepts he works with now. Nevertheless, the psychologist who is primarily a historian-psychologist remains uneasy. He feels that his professional ancestors are not recognized at their true level of attainment. The nature of human beings, as revealed by their behaviour and their reports of experience (to take no wider a field) is a continuing, enduring part of our world, as we contemplate it and ask ourselves questions about it. The sense of the word psychology may change, but the fact of solid, continuing, and sober contribution to the answering of these questions has been a feature of thought, European and other, for many centuries. (Sober at least in terms of effort, perseverance, and sincerity, if not in terms of concepts.) The impression which this article will try to specify and to substantiate, then, is this: given human nature (which has not changed radically in the past century), and given persistent effort to understand it, is it not likely that psychology will possess through that period a common body of subject-matter and attitude to it which will remain unaltered in essence despite change in method and approach? Does this mean that the non-experimental psychology of the earlier nineteenth century has been undervalued? Does it mean, further, that the pre-experimental psychology and the experimental alike are expressions in differing idioms of a basic perennial psychology, and that if either diverges from this the divergence is only apparent, or erroneous, or not relevant to psychology at all?

The importance of this argument, its difficulties, and its fruitfulness for understanding are best illustrated by an example. A persistent problem of psychology, experimental or not, is the vast growth in complexity, richness, modifiability, and effectiveness which the behaviour of living creatures exhibits as they progress from infancy to maturity. Part of the suggested explanation is that as creatures develop they acquire new motives. There are rival definitions of motive itself, but here we may take the broadest current one "any state or event within the organism that (under appropriate circumstances) initiates or regulates behaviour in relation to a goal."[1] Now let us compare and contrast a pre-experimental and an experimental discussion of the acquisition of motives, the appearance in the individual of states or events, as initiating behaviour which earlier in the life-history they did not do. For succinctness and ease of recollection we shall call these the case of the money-mad miser (pre-experimental) and the case of the cue-crazed ewe (present-day).

First, the old-time miser: just over a century ago the first great textbook in psychology appeared. Its author, Alexander Bain, is remembered for accurate, detailed, comprehensive, and indefatigable observation. His treatment of the miser (a familiar figure in previous literature) is selected therefore as likely to show the main features of pre-experimental method and approach, and to do justice to this kind of psychology.

> It is well-known (says Bain) that many things sought, in the first instance, as means, come, at last, to have a force in themselves, without any regard to those very ulterior consequences, but for which they would never have been taken up. The acquisition of money once commenced, one is apt to get a fascination for the thing itself, although, strictly speaking, that has no real value. The truth seems to be, that with the handling of the universal medium of purchase, a new susceptibility is developed, there being something in the form and manner of the object that commends it to the mind. A latent taste is incidentally made manifest, and the gratification of it brings a new end".[2]

Such is Bain's description of a familiar course of development, in which something that is not an original end of one's nature (such as the slaking of thirst) becomes such an end, a mover to action, through experience, or in more recent terms, through social learning, "a learning process in which social demands are the determining conditions".[3]

Second, the present-day sheep: this creature appears in a situation where, as R. S. Woodworth said in effect, "any means employed to reach a goal [cf. Bain's money] might subsequently become a motive in its own right, or, in terms of his own formulation, any mechanism might become a drive. In essence, this is the first formulation of the doctrine Gordon Allport came to label the 'functional autonomy of motives'".[4] This writer, D. B. Klein, then quotes at length from a study by H. S. Liddell on neuroses in sheep and goats. Liddell refers to "a source of annoyance and frustration in our study of learning", the "sheep's insistence on running through the maze for its own reasons—not for the reasons or 'motives' that we attributed to it".[5] The particular situation was, that the sheep (plural) were learning a maze (cf. money again) in which the reward (cf. the things money buys) was either food or return to the flock.

> "In spite of their invariable mistakes (continues Liddell), the normal sheep seemed eager to run the maze day after day. The experimenter, on coming into the barn to start the day's work, would regularly find these animals clustered about the screen-door leading to the maze as children congregate around the ticket-window for the Saturday-afternoon movie. When they reached the food-box at the end of the maze, they often did not delay there. One mature ewe was always in a hurry for the next trial. At the food box she rubbed her snout along the surface of the oats perfunctorily, sometimes taking a small bite, and in one continuously wheeling motion rushed off to the starting gate again . . . Her maze activity was completely absorbing. The sheep obviously was not motivated to exercise her defective skill in the alternating maze either by longing for the reward of food or by the prompting of a gregarious instinct. She ordinarily ate little or nothing from the box of oats and we found that shutting out the sight of the flock by closing the wooden storm door to the barn did not startle or disturb her. We may conclude that the running of the maze was a self-rewarding activity which was also self-perpetuating".[6]

Now as to resemblances and differences of these two examples. Firstly, Bain deals with human beings, Liddell with animals. Secondly, the former speaks of fascination, susceptibility, taste, gratification; the latter of reward, activity, and behaviour in detail, although he admits eagerness, absorption, and longing. Bain deals in terms of anecdote, Liddell in those of experiment.

The apparent contrast in the choice between human and animal behaviour is no contrast. Bain describes animal behaviour in detail elsewhere, especially in his early work *Animal Instincts and Intelligence*, where his view of psychology is remarkably "modern" in that he says "A mistaken fear of submerging the dignity of man should not prevent us from identifying the superior and inferior types of animal existence to the full extent of their agreement."[7] This view he justifies in the words: "the nervous system is the medium of all the instinctive, emotional, intelligent and active processes of the animal; in so far as it is similar in two different creatures, these processes are usually found to be similar."[8]

The difference between the anecdotal and the experimental aspects, however, is striking. The example above, since it is general or imaginative anecdote, might be held to over-stress the divergence between the old and the new psychology. But an instance more closely linked to fact will redress any unfairness in this respect. Thus Bain says elsewhere: "To discriminate hypochondria, or false alarm, from a mental depression indicative of actual disease, is singularly puzzling at all times; probably one aid in the discrimination might be furnished by enquiry, if the person was naturally susceptible to minute degrees of the healthy and unhealthy influences, as atmosphere and the like; in other words, whether there was originally a keen consciousness of organic states. The late Lord Jeffrey was a man of this sort".[9] As anecdote goes, this is closely linked to fact, to an individual. But it occurs (it was selected by chance) in an area where study is still clinical rather than experimental. It highlights the great observational attainment of Bain in personality study without lessening the gap between him and present-day writers, experimentally speaking. As to the contrast in vocabulary, the "inner-ness" of Bain's key terms, as opposed to the "outer-ness" of Liddell's, is obvious, and suggests a line of contrast to be recognized and evaluated.

Taking anecdotalism and "inner-ness" together, we have an indication of the serious indictment that can be brought against psychology before 1879. It is, that psychology then lacked the methodological ballast that experiment provides, and so was liable to be tossed about by the wild winds of speculation, imagination, and downright phantasy. To make matters worse, anecdotalism deprived psychology of the measure of anchoring that strict observation would have provided.[10] These attacks are serious, but not so uniformly damning to the pre-experimental psychology as many have thought. Leaving moderate authors like Bain for the moment, let us consider what really extreme writers, whether ancient or modern, can do. An author who consciously tries to combine the merits and avoid the defects of Hegel and Schleiermacher is not likely to be lucid, factual, or concise—"scientific", so to speak. Indeed he runs grave risk of plumbing depths of incomprehensibility never attained by his mentors.[11] The kind of psychology that emerges may be illustrated thus: both Hegel and Schleiermacher assume Being as the foundation of their systematic constructions (from which their psychologies stem). But Leopold George says that if Being is assumed, then one runs into systematic difficulties at once, and the only way to avoid these is to drop "all presuppositions and start with what scepticism itself never doubts, namely, nothing".[12] Thus George starts from a metaphysic with a catch in it. Building on this, and taking what he wants from Hegel and Schleiermacher, he produces an ordered explanation of reality by a system of categories which run in nines, with this result for psychology: "Since spirit is the sum and substance of all these categories, everything which proceeds from spirit is subject to them. Accordingly, therefore, thought is; and psychology in the part in

which it treats of thought, will have to show why thought is bound down by these definite rules ".[13] At one level this may appear to be explanation of the nature of the universe, at another the contriving of a bed of Procrustes which is also a labyrinth, in which the reader is lost and human nature contorted into strange and fearsome shapes. A standard historian of the period allows that this " contains some isolated points of value. But the systematizing spirit (he adds) overrules these tendencies and the work is cast in the dialectical form of a ninefold evolution out of nothing ".[14] Psychologically, the weakness of such a system is that the author's observation of experience is bound to come in conflict with his preconceived notions. For instance, in George's psychology motion plays a large part, " so large, in fact " (says Brett) " that one might seem to be reading a physiological introduction to psychology until the artificial character of the exposition is grasped ".[15]

This psychology (which is not the most extreme one can find) Brett characterized as a " curious mixture of sound sense and cosmic rhythms ".[16] The cosmic rhythms, not the sound sense, were the feature of it most admired at the time. The sound sense, on the contrary, is the element which will justify this, or any other pre-experimental psychology. Accordingly the next step in assessing the permanent merit of the old psychology is to see what minimum common element, what enduring substratum of reasonable reflection on human nature, it has with the new, and what gross divergences from it are fashionable, or have recently been so. Now, the most extreme contrast with George's cosmic psychology is the behavioural science (some even called it behaviouristics, not psychology at all) which aims to depend on data words (terms used in describing *what happens*,) and deprecates or rejects outright concepts which are intuitive, that is, according to these writers, " undefinable without the introduction of non-empirical, non-objective sets of referents, and hence . . . (without) place in scientific statement."[17] (These " intuitive " concepts are the very ones that a speculative or " cosmic " psychologist like George depends on most.) The writer just referred to, W. S. Verplanck, aims to provide " an empirical vocabulary that can be used by anyone in the science of ' human ' or ' animal ' behaviour ".[18] His general attitude may be fairly illustrated by two quotations. First, he remarks " I suspect that a major part of the behaviourist's problem is to provide a scientific account of how and why intuitive concepts are developed and used, that is, to ' explain ' them in terms of human verbal behaviour and discriminative control ".[19] This is the furthest concession Verplanck will make to intuition. He adds, however, that such concepts " do not belong in statements of fact or in statements of theory set up to deal with fact ".[20] Second, Verplanck's own personal experience of intuitive concepts is entirely negative: " the writer remains ignorant of what a *cognition* is. So far as he knows, he has never had one, and no one has ever been able to correct him on this, or tell him how to have one, or how to recognize it if he did ".[21] In fact, perfectly intelligible, widely accepted, middle-of-the-road definitions of cognition exist. English and English, for instance, do not recommend the vague popular use " the awareness of objects ". but they record without criticism the traditional meaning " a generic term for any process whereby an organism becomes aware or obtains knowledge of an object."[22] They quote also the behaviouristic definition " a hypothetical stimulus-stimulus association or perceptual organization inferred to account for expectancies ".[24] The reader may care to ponder these defiintions, follow up the cross-references which English and English provide, and note that they say also of this term " Although it is part of the *traditional terminology* and has subjective connotations, many neobehaviourists use (it) ".[25] If he does so, he will be well started on the way to judging how both " cosmic " and " scientific " psychologies may have their eccentricities, and how important the common element of common sense is.

More specifically, behaviouristic psychology, like that of George and his peers at the other extreme, is the end-result of a process. This process is that of working through the possible applications of a standpoint to the explanation of behaviour, with complete logic but incomplete common sense, and little if any humour in each case. The behaviouristic standpoint is this: that psychology must deal in terms of material fact, be philosophy-free, and enjoy entire immunity from intuition, feeling and what might be called the literary side of life in general. A statement (now itself historic) by J. B. Watson will indicate the basic doctrine which underlies all this: " It is granted that the behaviour of animals can be investigated without appeal to consciousness . . . The position is taken here that the behaviour of man and the behaviour of animals must be considered on the same plane . . .[26]

We have now shown the consequences of two extreme views of psychology, the one " old ", speculative, and metaphysical, the other " new ", experimental, and " non-metaphysical ". Both, it has been shown, can run into the dangerous position of transgressing the deliverances of experience as expressed in common sense, and experiment is no safer than speculation, let alone anecdote, in this regard. So far the old psychology is at no disadvantage. But two more radical issues now face us. First, metaphysics: is the affirmation of this a merit or demerit in the old psychology? Can we find an optimum proportion of metaphysical thought in psychology which will justify us for criticizing George as over-metaphysical and Watson as under-metaphysical, all in the same breath. Second (and more important) can it be shown that there was a central body of " old psychology " which agreed on allowing metaphysics at this level, whatever other divergences it showed?

On the first issue, metaphysics has been defined as " that branch of philosophy concerned with the ultimate nature of existence ".[27] This study, according to the writers quoted, has " no place in the science of psychology ", and metaphysical is a term of reproach, " nearly always ".[28] This would embrace propositions like those made by George about nothingness, and here we would have to agree. But English and English also recognize metapsychology. This, on one definition. is " a systematic attempt to deal with what lies beyond the empirical facts and laws of psychology "[29] It is " related to psychology as metaphysics was to physics in Aristotle's system "; it includes " the problems of relation of mind and body, of the place

of mind and behaviour in the cosmos, &c."[30] Curiously enough, English and English themselves refer elsewhere to the mind-body problem (the relation of mind, or that which is mental, to the body), as a metaphysical issue, going behind the empirical relationships to the ultimate one, often "unwittingly introduced" into psychology (and irrelevantly so, they argue) because of overlap between metaphysical and psychological terms.[31] This dictionary rightly reflects the major present day divergence of view on these matters. If one takes the position of some philosophers, that the problem is unreal, then one will side with Verplanck and Watson, to name only those we have mentioned, and "old" psychology is of no importance, though "old" physiology is. If, however, one allows that the mind-body problem is a real problem, and that the area called metapsychology is an area where meaningful propositions may be made, then the pre-experimental psychologies are worth considering, and while some may be erroneous, others may not.

Next, if you exclude mind (or soul or spirit for that matter) from psychology, you are assuming that it does not exist, *or* that its importance is negligible in relation to the understanding of behaviour, *or* that is is inaccessible to meaningful study, or possibly a variety of other things. In any case anti-metaphysical psychology assumes a metaphysical position, just as much as that which recognized metaphysics: in the study of human behaviour you cannot escape from the nature of things, and if you choose to ignore it you gravely limit the area of discourse. Our ancestors of a century ago were probably clearer on this point, for a dictionary then in current use recognizes that metaphysics can mean not only "*hyperphysical*, or that which is above and beyond nature", but also "if [meta] be interpreted, as it may, to mean *along with*, then *metaphysics* or metaphysical philosophy will be that philosophy which we should take *along with* us into physics, and into every other philosophy—that knowledge of causes and principles which we should carry with us into every department of inquiry"[32] This standpoint requires that you take the mind-body problem and the determinism-indeterminism problem with you into your psychology. But if you assume determinism, or deny mind, you have already limited the explanations you can give for behaviour.

Now ironically enough, Bain himself, who among the old psychologists is much honoured as the (unconscious) ancestor of behaviourism, did not allow metaphysics to prejudge psychological issues on the mind-body problem, though he did on determinism. Sometimes, indeed, he is accused of skating round the real body-mind problem. Those critics are more correct who remark that he "avoided the apparent crassness of a mechanistic system. He mades use of physiological principles for their practical usefulness, not for philosophical purposes".[33] The outcome of this, to follow R. S. Peters' version of Brett's famous history, is that Bain holds mind and body to be "one, a double-faced unity"; "We are to deal with this, in the language of the Athanasian Creed, not confounding the persons nor dividing the substance" (Bain's own words), and Bain was a true Aristotelian in his "grasp of the ideas of organism and activity".[34] Though his method was the method of natural history, Bain's psychology remains a psychology with a metaphysic behind it.

The pre-experimental psychology has now been shown, even if rather *en passant*, to have, at least in one of its central authors, not only a recognition of metaphysics, but discernible signs of kinship with Aristotle, the founding father of the whole discipline. Nevertheless, the question still remains, was there *an* old psychology different from the various new psychologies? The contrast between George and Bain would seem to indicate that there was not. However, a contrary view is possible. To demonstrate this, consider an author in some ways as different from Bain as is George. This was James McCosh, competitor with Bain for various academic appointments, Calvinist, whereas Bain was agnostic, a clergyman whereas Bain was anti-clerical, right-wing whereas Bain was radical. Now, McCosh (writing about the same time as Bain in the first edition of *The Emotions and the Will*) defined the task of psychology as inquiry "into the operations of the mind of man with the view of discovering its laws and its faculties".[35] The most important aspect of this task, in relation to our previous argument, is the relation of psychology to the other moral sciences in the performance of it. For McCosh, logic is the basic science of the laws of thought, and metaphysics that of the nature of being. But logic "throws us back on Psychology, not indeed to justify the laws, but to discover them",[36] nor can metaphysics "attain anything like a scientific form, till psychology has made some progress, and taught us to distinguish between intuition and associated and allied states of mind".[37] Psychology, here, is in the midst of the moral sciences, in the role not of master, nor servant, but of partner. Bain would not admit intuition in the same way as does McCosh, but he would agree on the need for the distinction between it and allied states. Moreover, Bain admits and stresses "consciousness, or the immediate feeling of the mind's doings".[38] This is an allied state (immediate feeling), though Bain remarks that "this has been too much looked upon by metaphysicians as the main source" of "knowledge respecting the Human Mind".[39]

Bain's two other sources, however, although diverging from those of McCosh, agree with those favoured in even less likely quarters. His recognition of the "anatomy and physiology of the human framework"[40] as a source of information about the mind, has already been noticed under other names: it forms a link with the physiologically minded psychologists from the eighteenth century (at least) to Watson. The difference is that the materialists and behaviourists did not keep this source in perspective as Bain did, and tried to reduce the products of the others to it. On the other side, Bain's emphasis on this third source, "Outward appearances, actions, and works", provides links with writers who themselves err by sectional over-emphasis. Thus Comte tried to reject introspection and the deliverances of consciousness in general and to reduce psychology to biology plus a social science yet to be developed, thus emphasizing two of Bain's three sources to the detriment of the third.[41] Other pre-experimental psychologists who overstressed the introspective sources could easily be cited besides George.

Once this principle of the three necessary sources of psychological knowledge is established, the central tradition of the old psychology becomes clear. This tradition considers events in life-histories as acts of whole creatures, not bits of behaviour, it accepts the organism as a unit, it listens to what talking organisms say about themselves, it has a place for the study of cultural artifacts as well as the twitching of muscles, for description of the phenomena of mind, as well as for the reporting of behaviour. On this basis, the alleged change from old to new with the coming of experiment appears rather as a suppression of one or two of the sources in the interest of "science", or of introspection, or of any other point of view or method of gathering information. Admitting this, the old or perennial psychology, the psychology of the three sources, is well represented in the days before Wundt, for instance by G. H. Lewes, Herbert Spencer, Lotze, and many more whom one would even less expect to see bracketed together. On this showing, there is a place in it for Wundt and Brentano, though many other famous reputations would need some re-valuing. This is material for future studies, however: for the moment it must be enough to have sketched the *prima facie* contrast between pre-experimental and experimental psychology, to have indicated that this contrast is not quite what it seems, and to have argued that the old psychology is in fact a perennial one, dependent on the recognition of the three sources which have been mentioned.

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* Based on a paper read before the Royal Society of Tasmania, April, 1961.

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[2] Bain, A.—*The Emotions and the Will.* London: Parker, 1855, pp. 429-430.

[3] English and English, *op. cit.*, p. 292.

[4] Klein, D. B.—Psychopathology, Chap. XII in Seward, C. S. and Seward, J. P. (Eds.), *Current Psychological Issues.* London: Methuen, 1960, pp. 303-328, at p. 309. First published New York: Holt, 1958.

[5] Liddell, H. S.—Conditioning and Emotion. *Scientific American*, 1954, *190*, pp. 48-57, at p. 51.

[6] Liddell, H. S., *op. cit.*, p. 51. Also in Klein (to whom I am indebted for the reference), *op. cit.*, p. 309.

[7] Bain, A.—Animal Instincts and Intelligence. In *Chambers' Papers for the People.* Edinburgh: W. and R. Chambers, 1850. Vol. 6, No. 82. Pp. 1-32, at p.1.

[8] Bain, *op. cit.*, pp. 2-3.

[9] Bain, A.—*The Study of Character.* London: Parker, 1861, p. 225.

[10] See Thouless, R. H.—*General and Social Psychology.* London: Univ. Tutorial Press, 1937, pp. 8-14, Thouless castigates "fantastic anecdote", a "pre-scientific method", consisting in the "use of an anecdote which is not an account of an actual event, but of one invented by the writer for the purpose of his argument" (*op. cit.*, p. 10). English and English are slightly less severe on anecdotalism. They say, under *anecdotal evidence*: "casually observed incidents. The evidence is seldom reportable in sufficient detail to be trusted for generalizations, but it is often a source of hypotheses for further investigation" (*op. cit.* p. 30).

[11] Ziegenfuss, W.—*Philosophen Lexikon*, Berlin: de Gruyter, 1949, says he was "beeinflusst von Schleiermacher und Hegel" Vol. I, p. 383); Baldwin, J. M., *Dictionary of Psychology and Philosophy, Gloucester*, Mass., Peter Smith, 1960 (originally Macmillan, 1901), adds: "He attempted to synthesize the philosophical principles of Hegel and Schleiermacher" (Vol. I, p. 412). Friedrich Ueberweg, one of the greater historians of the period, describes George as developing "an enneadic system of dialectical development, in which it was claimed that the systems of Schleiermacher and Hegel received their natural complement or final development" (*A History of Philosophy*, translated from the fourth German edition by G. S. Morris, 4th ed., London: Hodder and Stoughton, 1885, vol. II, p. 307).

[12] Erdmann, J. E.—*A History of Philosophy*, English translation edited by W. S. Hough, London: Swan Sonnenschein, Vol. III, p. 220, 1899.

[13] *Op. cit.*, p. 223.

[14] Brett, G. S.—*A History of Psychology*, London: George Allen and Unwin, 1921, Vol. III (Modern Psychology), p. 85.

[15] Brett, *op. cit.*, p. 112.

[16] *Loc. cit.*

[17] Verplanck, W. S.—A Glossary of Some Terms used in the Objective Science of Behaviour, *Psychol. Rev.*, 1957, 64, (No. 6, pt. 2), pp. viii + 42, at p. iv.

[18] *Op. cit.*, p. v.

[19] *Op. cit.*, p. iv.

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[21] *Op. cit.*, p. iin.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 96

# FOSSIL INSECTS FROM THE TRIASSIC AT HOBART, TASMANIA

By

E. F. REIK*

Communicated by Maxwell R. Banks

(With two figures.)

## SUMMARY

A new locality for Australian Triassic insects has been discovered at Hobart, Tasmania. A plant-bearing horizon has yielded three insect fossils belonging to the Blattodea and Homoptera. Both the cockroach and the bug can be compared with similar fossils in the Mt. Crosby Triassic.

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A plant-bearing horizon in the Triassic rocks at Hobart, Tasmania, has yielded three quite well preserved insect fossils. Dr. J. A. Townrow, University of Tasmania, collected the specimens from the Hobart Brick Co. quarry at the junction of Forster and Giblin Streets, New Town. In the northern end of the quarry two coal seams are exposed. The lower one, overlain by feldspathic sandstone, is underlain by grey mudstone. About three feet below this lower seam on the eastern wall of the quarry, fossil ferns occur and with these the insect wings are associated in the grey mudstone. The rocks are part of the New Town Coal Measures. I am much indebted to Mr. M. R. Banks of the University of Tasmania for the opportunity of examining this fossil material and for the stratigraphical details concerning them. In one specimen the counterpart was also recovered. Two of the specimens are cockroach wings and the third is the basal portion of the forewing of a bug.

Cockroaches are unknown from the Australian Permian but are very common in the Triassic. The group to which the bug belongs was very common in the Australian Permian and persisted into the Triassic. The two fossil species taken in conjunction would confirm the approximate age determination of the strata based on the abundant plant material.

## BLATTODEA.

### POROBLATTINIDAE.

### *Triassoblatta* Tillyard.

This genus was placed by Tillyard (1919) in the Mesoblattindae in preference to the Poroblattinidae after consideration of all characters of the forewing. The genus shows the transition in characters from the mainly Permian Poroblattinidae to the mainly Mesozoic Mesoblattinidae. Dodds (1949) transferred the genus to the Poroblattinidae. The genus resembles the Poroblattinidae in the structure of Sc and of the clavus but it has the long narrow wing of the Mesoblattinidae with the associated straightening of the stem of R. As the presence or absence of branching of Sc is a more clearly defined character than the curvature of R the genus is retained in the Poroblattinidae.

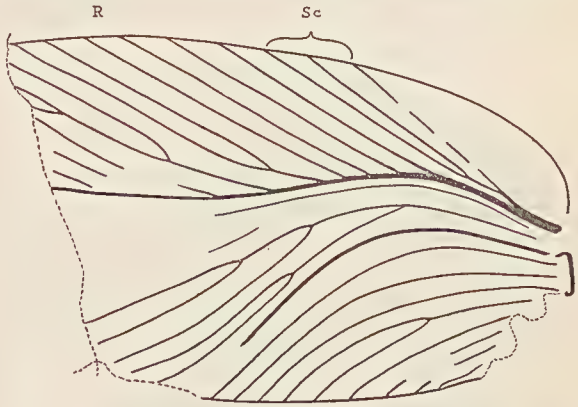


Fig. 1.—*Triassoblatta tasmanica* sp. nov. Forewing X6.

*Triassoblatta tasmanica* sp. nov.

Holotype, forewing fragment 55138 and counterpart 55136, University of Tasmania, Department of Geology Collection.

Type locality and horizon: Hobart Brick Co. Quarry, Forster and Giblin Streets, New Town, Tasmania. in the New Town Coal Measures.

Basal two-thirds of forewing preserved, length 12mm. but distal 2mm. crushed and venation obscure; clavus preserved; slight rupturing along suture of clavus and basal portion of stem of R; costal space short and triangular; Sc three-branched, the basal branch not strong; R with the anteriorly directed branches mostly simple; M not clearly preserved; CuA weak, sigmoidally curved dichotomously branched, with few branches; CuP strongly curved but joining the caudal margin at an oblique angle; anal veins mostly simple, joining the caudal margin, except that the first may join CuP just before the margin.

As there is considerable individual variation in the wings of cockroaches it is difficult to compare this fossil with the described wings placed in the genus. However, this Tasmanian specimen is more similar to *Triassoblatta ovata* Dodds than to any other species from the Triassic beds at Mt. Crosby, Queensland.

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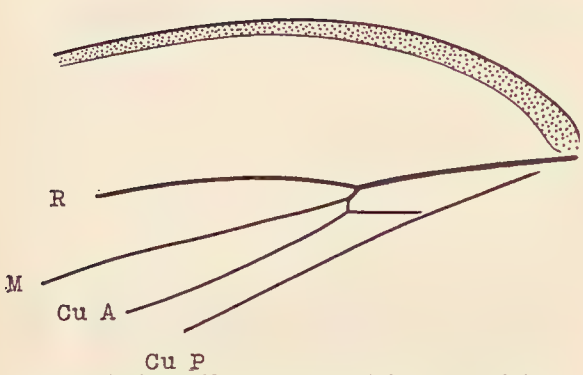


FIG. 2.—Scytinopteridae, gen. et sp. indet. Base of forewing X6.

## HOMOPTERA.

### SCYTINOPTERIDAE.

### gen. et sp. indet.

Specimen 55140, University of Tasmania, Department of Geology Collection.

This specimen (length of fragment 12 mm.) consists of the basal third or more of the forewing of a rather large homopteron. Only the costal field and the basal stems of R, M, CuA and CuP are preserved. The enlarged costal space, curvature of R, origin of M and shape of CuA indicate affinity with the Scytinopteridae or with the Prosbolidae. These two families are separated on structures which occur in the apical half of the wing. However, the Prosbolidae are not definitely recorded from Australian strata although one or two fossils have provisionally been placed in the family. The Scytinopteridae are the dominant family of Australian Permian Homoptera and are also well represented in the Triassic. It is therefore more reasonable to consider this fossil as a scytinopterid.

A comparison with Australian Scytinopteridae shows a close similarity between the present wing fragment and the corresponding portion of the forewing of *Orthoscytina*, a genus common in the Upper Permian of Belmont, New South Wales. It could, however, be as readily compared with several of the Triassic Scytinopteridae from Mt. Crosby, Queensland, where the origin of Rs is more distal though in most of these forms the base of R is arched.

As the diagnostic features of the wing in species of this family are all apical the specimen must remain unnamed though it is distinguished from other known species by its large size.

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# RECOVERY FROM RADIATION AND CHEMICALLY INDUCED PREMUTATIONAL DAMAGE

By

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## ABSTRACT

The question of recovery from radiation and chemically induced premutational damage is discussed in relation to the nature of the primary genetic damage at the molecular level, and also in relation to factors which influence the recovery process.

## INTRODUCTION

Following Muller's (1927) discovery that gene mutations could be produced artificially in *Drosophila* by X-irradiation, subsequent investigations showed that X-rays, other ionizing radiations, ultra-violet light, and certain chemical substances produced mutations in a wide variety of organisms. However, it is only in comparatively recent years that the processes involved in the induction and expression of artificially produced mutations have been studied in any detail. Already it has become evident that these processes are subject to modification, and as a result the induced mutation frequency can either be increased or decreased depending on the nature of the modifying treatment. Hypotheses, which have been put forward in recent years, relating to the physical structure and mode of replication of genes at the molecular level, have served to stimulate these investigations by placing the study of mutation on a molecular basis.

Investigations carried out with bacteriophage (Zinder, 1955) and studies on bacterial transformation (Hotchkiss, 1955) strongly suggest that deoxyribonucleic acid (DNA), which is an important constituent of the chromosomal material, carries a part, if not all the genetic information. In the light of the model proposed by Watson and Crick (1953) to account for the structure and mode of replication of DNA, and of recombination experiments in bacteriophage, Benzer (1957) has proposed that the gene consists of a finite section of DNA containing a large number of small units (sites), which are inseparable by recombination experiments, and which may actually correspond to a single nucleotide pair or a few nucleotide pairs. An induced change (mutation) at any one site alters the expression of a gene, but changes at different sites within the gene locus alter the expression of the gene in different ways. Thus the presence of several alleles at any one locus, may, at the molecular level of the gene, be represented by mutations at several different sites within that gene locus.

On the basis of this model, there are a number of possible ways in which mutation could occur, some representing changes in an existing gene molecule, while others might be related to the synthesis of DNA and the replication of the gene.

(*a*) *Changes in already existing genes.*

(i) Loss of one or more nucleotide pairs.

(ii) Duplication of one or more nucleotide pairs.

(iii) Loss of a base pair with the subsequent incorporation of an alternative base pair into the DNA molecule, or loss of a single base from one DNA strand and its replacement by an alternative base—with the incorporation of its complementary base in the other strand during DNA replication.

(iv) The chemical alteration of a base, with its resultant change in behaviour leading to the incorporation of a different base in the complementary strand during DNA replication.

(v) Fracture of the sugar-base bonds of a complementary pair of nucleotides, followed by the rotation of the attached base pair before re-establishment of the bonds.

(vi) Intragenic changes produced by the inversion of two or more nucleotide pairs following breakage of complementary phosphate-ester linkages in both strands —four breaks in all.

(*b*) *Changes which are dependent on DNA synthesis for their induction.*

(i) The chemical alteration of nucleic acid precursors with their subsequent incorporation into the DNA (or ribonucleic acid (RNA)?) molecule.

(ii) A "copying error" during DNA replication in which a segment of DNA formed on an adjacent template or modified template (modified RNA protein template?), is incorporated into the daughter strand.

In addition to point mutations, other types of genetic damage involving chromosome breakage, for example, translocations, inversions, deletions, duplications and position effects, are all produced by radiations, as well as by some of the chemical mutagens. An understanding of the basic structure of the chromosome is necessary, in order to facilitate the study of processes involved in chromosome breakage and restitution. Our knowledge of chromosome structure is still somewhat fragment-

ary, but it is apparent that, chemically, the chromosomes are made up of nucleic acids and proteins. Structurally they consist of bundles of fibrils, the number of which varies in different organisms, but it is believed to be always some multiple of two (Ris, 1957). The exact arrangement of the nucleic acids and protein within the fibrils is not yet known, but it is thought that there is a central core of nucleic acids surrounded by an outer "coat" of protein.

It is very likely that different mutagenic agents induce genetic changes of different types or at least the same changes in different relative frequencies, whilst the same mutagen may produce mutations of different types in different organisms. Also, it is likely that treatments which bring about recovery from one type of mutational damage. will be ineffective against other types. Consequently, investigations into the recovery from induced genetic damage will not only help determine what types of damage are repairable, and the mechanisms involved in this repair, but they will also help to elucidate the steps involved in the production of the various types of mutations, and determine whether any of these steps are the same for radiation and chemically induced mutations.

It should be emphasized that treatments which modify the mutation frequency may not necessarily do this through interference with the recovery mechanism, but may either increase or decrease the amount of primary damage.

## I. RECOVERY FROM RADIATION INDUCED MUTATIONS

### A. Bacteria

Recent investigations have shown that at least a portion of ultraviolet (UV) induced mutations require protein synthesis (Witkin, 1956) as well as RNA synthesis (Doudney and Haas, 1959) for mutation fixation, whilst the terminal process in the induction of mutation apparently involves DNA synthesis (Haas and Doudney, 1959, 1960).

Witkin, in her experiments with the tryptophane requiring LT2 strain of *Salmonella typhimurium*, showed that post-irradiation incubation with the antibiotic chloramphenicol, an inhibitor of protein synthesis, reduced the frequency of induced prototrophs, whilst the frequency of survivors remained relatively unchanged. Thus the reduction in mutation frequency could not have been due to selection. Subsequently Doudney and Haas, in their experiments with the tryptophane requiring WP2 strain of *Escherichia coli*, found, by "challenge" with chloramphenicol or the base analogue, 6-azauracil, at various times after irradiation, that a relationship exists between the frequency of mutations "fixed" and the amount of RNA synthesized. Mutation fixation is apparently complete when the amount of RNA in the culture has doubled. DNA synthesis then begins and this apparently is the final step in mutation induction, since following DNA synthesis mutations are no longer susceptible to photoreversal (Haas and Doudney, 1960). Mutation expression is apparently dependent on protein synthesis, for it can be prevented by treatment with chloramphenicol following the initiation of post-irradiation DNA synthesis, although the synthesis of DNA itself is unaffected (Haas and Doudney, 1959).

Investigations carried out within the last two or three years (Doudney and Haas, 1960a, b), have confirmed Witkin's observation that when chloramphenicol is added to incubating cultures immediately after irradiation, a decrease in mutation frequency occurs. However, Doudney and Haas found that a treatment of twenty minutes was sufficient to obtain maximum reduction in mutation frequency. Further treatment merely delayed synthesis of protein and RNA in the culture and this in turn led to a delay in DNA synthesis, but there was no further reduction in the mutation frequency. As a result of this finding Doudney and Haas (1960b) have proposed that "mutation frequency decline" is favoured by conditions which inhibit protein synthesis. However, this synthesis is not correlated with the macromolecular synthesis within the culture which leads to mutation fixation. Furthermore, "mutation frequency decline" is apparently an enzymatically controlled process, dependent on cellular respiration, since dinitrophenol (DNP) has been found to block the "mutation frequency decline" process promoted by chloramphenicol treatment. If "mutation frequency decline" does not occur, then the premutational damage induced by UV is stabilized within the cell (mutation stabilization), and this stabilization process is apparently dependent on a supply of amino acids and conditions which favour protein synthesis.

Since mutation fixation is apparently dependent on macromolecular synthesis within the culture, it is evident that RNA and protein may play a part in DNA replication. The exact nature of DNA replication is still not known. However, Delbruck and Stent (1957) have found evidence in bacteriophage that it may involve an intermediary substance which may be nucleoprotein. This finding, therefore, would tend to support the views of Doudney and Haas that DNA replication in bacteria involves an RNA-protein intermediate.

Kanazir and Errera (1956) have found that DNA synthesis is temporarily inhibited following UV exposure in *E. coli*. This temporary inhibition may be due to a blocking of normal DNA synthesis, whilst resumption of synthesis may be brought about by the substitution of an alternative mechanism. It may be that this alternative mechanism involves the necessity of an RNA-protein intermediate, whilst normal DNA synthesis in the undamaged cell is along the lines originally proposed by Watson and Crick (1953). However, this is only speculation, and the actual role of RNA and protein in the production of UV induced mutations in bacteria has still to be determined.

Recent investigations carried out by Witkin and Thiel (1960) have shown that some UV induced mutations are apparently stable, since they fail to respond to the post-irradiation treatments which modified the frequency of the UV induced mutations discussed above. Thus, whereas the frequency of mutation from *try*− to *try*+ is modified by post-irradiation treatment with chloramphenicol, the mutations from streptomycin sensitivity (*str* — *s*) to streptomycin resistance (*str* — *r*), and from

streptomycin depencence (*str — d*) to streptomycin independence (*stri — i*) were not affected by this treatment. Furthermore, Kada, Doudney and Haas (1961) have shown that X-ray induced mutations in bacteria are of two types; those whose frequency can be modified by post-irradiation treatment and those which fail to respond to these treatments. Thus Kada and his co-workers found that following X-irradiation of the WP2 and 15 *thy met tyr* (a thymine, methionine and tyrosine requiring strain) strains of *E. coli*, approximately half the mutants at the *try* and *tyr* loci respectively were expressed phenotypically in the absence of DNA synthesis, the other half requiring DNA synthesis for induction. "Challenge" with chloramphenicol or 6-azau-racil during DNA synthesis showed that both types of mutations require protein synthesis for mutation expression.

The existence of these two types of mutations after UV and X-irradiation suggests that the primary damage is induced at two different sites. Thus in the case of those mutations whose frequency is modified by post-irradiation treatment with chloramphenicol, the initial damage may be to the nucleic acid precursors. Haas and Doudney (1957) have shown that addition of cytidine and uridine to cultures prior to irradiation increases mutation frequency, whilst the addition of these same compounds after irradiation decreases mutation frequency. On the basis of this finding, they have suggested that the addition of the compounds after irradiation reduces mutation frequency because of the competition between the added compounds and UV modified nucleic acid precursors for incorporation into RNA during its post-irradiation synthesis. On the other hand, the increase in mutation frequency resulting from the addition of the compounds prior to irradiation is presumbaly due to UV modification of the added compounds and their subsequent incorporation into RNA. Those mutations which fail to respond to post-irradiation treatment may be produced by the direct action of the radiation on the genes (deletions or intragenic inversions in the DNA molecule ?), such mutations being phenotypically expressed without the necessity of DNA synthesis.

### B. Paramecium

Kimball, *et al.* (1957) have shown that in *Paramecium*, a portion of the X-ray induced premutational damage does not become finally established as an irreversible mutation until about midway through the interdivision period. They have found that incubation in streptomycin following irradiation produces a decrease in the mutation frequency, a treatment of four hours being sufficient to produce maximum mutation reduction. However, it was found that if the treatment was given at successively later intervals following irradiation, its modifying influence on the mutation frequency was progressively reduced. Further work by Kimball and his associates (Kimball, *et al.*, 1959) with stationary phase *Paramecia* has shown that there is a progressive decrease in the mutation rate during post-irradiation starvation.

On the basis of these two findings, Kimball and his co-workers propose that up to a point midway through the interdivision interval (called the intermediate period by Kimball) the induced premutational damage undergoes spontaneous reversal and only that premutational damage which remains at the end of this period becomes "fixed" as a permanent mutation. This "fixing" may be correlated with DNA replication. Kimball suggests that an increase in the time available for loss of premutational damage is the main factor responsible for "mutation frequency decline". However, it is likely that "mutation frequency decline" in *Paramecium*, as in bacteria, is a metabolically controlled process dependent on respiratory energy, since the rate of loss during exponential growth of paramecia was found to be very much greater than the rate of loss in stationary phase paramecia. Thus it is more likely that reduction in mutation frequency is not a spontaneous process and consequently is not increased by the lengthening of the interdivision interval, but is an active metabolic process dependent on a source of energy, but quite independent of the length of the intermediate period.

### C. Drosophila

Independent investigations carried out by Nordback and Auerbach (1957), Abrahamson and Telfer (1956), and Lüning (1958) have shown that fewer translocations are found in mature sperm used on the second day after irradiation of males than on the first day. The frequency of other genetic changes, for example, sex linked lethals or Y chromosome loss, also seem to be lowered by storage of mature sperm in males following irradiation.

The translocation results would suggest that some restitution of induced breaks occur when the sperm are stored in the irradiated males. However, Oster (1955) has found that following irradiation of pupae, breaks induced in mature sperm remain open until fertilization, although breaks induced in spermatids apparently undergo restitution prior to fertilization. It is probable, however, that the environmental conditions experienced by the mature sperm in the pupal testes and in the testes of the adult fly may differ in some respects. Consequently, the fact that no restitution occurs in the pupae does not necessarily mean that no restitution occurs in the adult. Although mature sperm are relatively anoxic in *Drosophila* males, the oxygen tension may be sufficient to allow some restitution of the induced breaks before fertilization.

Alternatively, we may suppose that the initial effect of the radiations is not the breakage of the chromosomes, but the alteration of the chromosomes in such a way that breaks may be produced if the post-irradiation conditions are favourable (Thoday, 1953). On the basis of this hypothesis, it is evident that conditions in the testes of male imagos are favourable for the repair of these "potential" breaks, whilst conditions in the pupal testes and also in the spermathecae and seminal receptacle of females are unfavourable for this repair, since it has been noted by many workers that no reduction in translocation frequency or other types of genetic damage occurs when irradiated spermatozoa are stored in the spermathecae of inseminated females. Perhaps the transfer of the mature sperm from male to female or conditions within the spermathecae result in the transforma-

tion of potential breaks into actual breaks. Assuming that there is recovery from potential breaks when irradiated spermatozoa are stored in the males, the question arises whether this recovery is a spontaneous process dependent on time or whether it is an energy requiring process. In the latter case the metabolic activity of mature sperm must be sufficient to enable recovery to occur.

The question also arises whether there is recovery from point mutations when mature sperm are stored in irradiated males. Lüning, Schuwert and Jonsson (1958) and Lüning and Söderström (1957) have shown that breakage followed by restitution in the original order does not appear to have any influence on the frequency of sex-linked lethals. Hence, the decline in frequency of sex linked lethals following storage, reported by Nordback and Auerbach (loc. cit.), may be due to a reduction in position effect lethals, since it is accompanied by a similar fall in translocation frequency and was of the same magnitude.

The effect of the presence of oxygen during irradiation on the production of genetic damage, and also on the recovery mechanism in mature spermatozoa has been the subject of extensive investigation in recent years. Lüning and Hannerz (1957) and Lüning and Söderström (1957) have suggested on the basis of their findings using dose fractionation, that the initial amount of primary damage is the same after irradiation in nitrogen as after irradiation in air. Thus they conclude that irradiation in air apparently affects the recovery mechanism in some way. Furthermore, Lüning and Henze (1957) have shown that for a given total dose of 6480 r, increasing the proportion of this dose given in air up to 1080 r increases the amount of damage produced, but that no further increase occurs if the dose given in air exceeds 1080 r. They regard this saturation phenomenon as due to a complete inactivation of the rejoining system produced by doses in excess of 1080 r in air. However, Sobels (1961) does not support this proposal, since he has found that post-irradiation treatment with cyanide inhibits recovery to the same extent, irrespective of whether the irradiation is given in nitrogen or oxygen.

The recent findings of Wolff and Lindsley (1960) corroborate the findings of Lüning and his associates, that dose saturation occurs when the irradiation is carried out in air, but in experiments in which doses were administered in pure oxygen, no such dose saturation was observed. To account for this apparent anomaly Wolff and Lindsley have suggested that there may be two oxygen sensitive systems; the rejoining system which is sensitive to low oxygen tensions, and breakage, which is relatively insensitive to low oxygen tensions but is affected by high oxygen tensions. This is similar to the model proposed to explain the oxygen effects in root tips of *Vicia faba* (see below, Wolff and Atwood ,1954). Although no experimental evidence exists to support this proposal, it would be reasonable to assume that the various cellular components affected by irradiation will suffer damage to variable degrees depending on physiological conditions during and immediately after irradiation, different components being affected to different extents by these conditions.

Sobels (1960, 1961) has shown that recovery in *Drosophila* is apparently dependent on cellular respiration, since he has found that post-irradiation treatments with cyanide or azide increase the frequency of mutations (in this case sex linked lethals) produced in the spermatid stage. That this increase in mutation frequency is not due to an increase in the number of position effect lethals resulting from chromosomal rearrangements, but is due to an increase in the number of point mutations and small deletions, is shown by the fact that after irradiation at low intensities, translocation frequency is increased by post-treatment with cyanide, but the frequency of sex linked lethals remains unaltered. Also post-treatment following irradiation at high intensities increases the frequency of sex linked lethals induced in a ring-X chromosome. Cyanide itself has been found to be nonmutagenic in *Drosophila* (Sobels, 1954), whilst the original proposal that cyanide blocked the catalase system, thus allowing the accumulation of radiation produced mutagenic peroxides (Sobels, 1957), has been made untenable by the finding that post-treatment with cyanide enhances mutation frequency to the same extent, irrespective of whether the irradiation is carried out in nitrogen or oxygen (Sobels, 1960).

The premutational damage produced in spermatozoa and spermatids by X-irradiation presumably alters the pre-existing gene, since no DNA replication occurs until the time of the first cleavage in the fertilized egg (Muller, *et al.*, 1961). The finding of Altenburg and Browning (1961) that no quarter mosaics are produced following irradiation of sperm and spermatids supports this view.

Altenburg and Browning have also shown that very few half mosaics are produced following irradiation. This suggests that the radiation affects both strands of the DNA molecule and not just a single strand. As mentioned earlier, changes involving both strands of the DNA molecule may be produced by duplication or deficiencies of one or more base pairs, intragenic inversions or by rotational substitution. It may be that restitution of the sugar-phosphate linkages or sugar-base bonds broken by X-irradiation, is delayed by post-treatment with cyanide or other respiratory inhibitors, thus allowing more time for rearrangement of the detached nucleotides or base pairs respectively.

Although mutations produced in spermatozoa and spermatids seem to involve changes in the already existing gene, it may be that mutations produced in younger germ cell stages may depend on DNA replication for their induction. Perhaps treatments which proved effective in modifying mutation frequency in bacteria (e.g., chloramphenicol) may be effective in modifying the mutation frequency in younger germ cell stages in *Drosophila*.

**D. Plants**

Thoday and Read (1947) showed that irradiation of *Vicia faba* root tips in the presence of oxygen produced more genetic damage than irradiation in anoxia. It became apparent from further investigations in *Vicia* (Wolff and Atwood, 1954) and *Tradescantia* (Wolff and Luippold, 1958) that oxygen affects both breakage and rejoining of the broken chromosomes. However, apparently only the time of rejoining, and not the amount of rejoining is

affected. Therefore the decrease in aberration yield when the irradiation is carried out under anoxic conditions is due to fewer breakages being produced and not to increased restitution, although restitution occurs more rapidly after irradiation in nitrogen compared with the rate of restitution after irradiation in oxygen. Wolff and Luippold (1955) have also found that agents which inhibit oxidative metabolism such as low temperature, cyanide, carbon monoxide, anaerobiosis and DNP, increase the length of time that breaks remain open. From this it is apparent that chromosome restitution is an energy requiring process and therefore dependent on cellular respiration and the formation of ATP. Small amounts of oxygen are apparently sufficient to permit oxidative metabolism and therefore facilitate chromosome restitution. The addition of exogenous ATP, or of $MnCl_2$, which stimulates ATP synthesis in the mitochondria (Ernster and Low, 1955), enhances the repair process (Wolff, 1960).

Recent investigations (Wolff, 1960) with *Vicia faba* have shown that protein synthesis is necessary for the restitution of radiation produced chromosome breaks, since application of chloramphenicol and other protein synthesis inhibitors, notably aureomycin prevents restitution of chromosome breaks. How protein synthesis promotes chromosome restitution is not known, but Wolff has suggested that it may either involve direct action such as the synthesis of a peptide link or indirect action resulting from the formation of an enzyme or enzymes which may be necessary to promote the restitution of breaks.

### E. Mice

Recent work by Russel, Russel and Kelly (1958) suggests that recovery from premutational damage may not be confined entirely to "lower organisms", but may actually occur in the spermatogonia and oocytes of mice following chronic irradiation. They found that specific locus mutation rates were lower after chronic gamma—irradiation than after acute X-irradiation in the spermatogonia and oocytes, but not in the mature spermatozoa. It was found that this difference in the mutation rate was not due to qualitative differences in the nature of the radiations, nor was it due to cell selection. To explain these findings, Russel and his co-workers have suggested that following irradiation at low intensities, a part of the premutational damage is repaired before it becomes finally established, but after irradiation at high intensities there is apparently no repair, presumably because the repair mechanism is damaged by acute irradiation. The failure of the spermatozoa to show any intensity effect is assumed to be due to the relatively low metabolic activity of the mature sperm compared with the spermatogonia and oocytes.

The existence of an intensity effect in certain germ cell stages of the mouse is of interest because of the conflicting results obtained with high and low dose rates in *Drosophila* (Clark, 1960a). Should further experimentation show that this intensity effect in the spermatogonia and oocytes of the mouse is due to differential recovery following chronic and acute irradiation, then perhaps this recovery phenomenon will need to be taken into account when determining the genetic as well as the somatic hazards of ionizing radiations in human beings.

## II. RECOVERY FROM CHEMICALLY INDUCED MUTATIONS

In contrast to the extensive investigations that have been carried out on recovery from radiation induced premutational damage, very few investigations have been carried out in order to determine whether chemically induced premutational damage is also subject to modification, and if it is, whether it is due to recovery.

Clark (1958) has found that injection of either cyanide or azide in *Drosophila* males failed to increase the mutagenic activity of injected pyronin. However, Sobels (1956), and Sobels and Simons (1956) have reported that the formaldehyde induced mutation frequency in *Drosophila* males and females respectively is enhanced if formaldehyde injection is preceded by treatment with cyanide gas. It has been suggested that this enhancing effect of cyanide is due to a blocking of the catalase enzyme system, which allows the accumulation of formaldehyde produced organic peroxides, the presence of these peroxides resulting in an increase in mutation frequency. If this explanation is correct, then the enhancement of mutation produced by cyanide gas is not due to interference with a recovery mechanism, but is due rather to a mechanism which increases the amount of primary genetic damage by allowing mutagenic peroxides to accumulate as a result of the inhibition of catalase.

The main groups of chemical mutagens are reviewed by Röhrborn (1960). Investigations carried out in recent years have done much to determine how the alkylating agents (see, for example, Stacey, *et al.*, 1958, Bautz and Freese, 1960, Fahmy and Fahmy, 1961) and formaldehyde (Alderson, 1961) react with the genetic material.

Alexander and Stacey (1958) discuss the genetic changes produced by radiations and alkylating agents. Undoubtedly the end results are the same, that is, the production of chromosome breaks and mutations, but it is still doubtful whether the intermediate steps are the same. The polyfunctional alkylating agents are much more potent with regard to the production of chromosome breaks than the the monofunctional agents. Both groups of compounds are capable of breaking the phosphate-sugar bonds, although the polyfunctional agents, by forming cross-linkages between the two complementary strands of the DNA molecule, will be more effective in producing breaks in both strands (Fahmy and Fahmy, 1961). However, the mere breakage of the "backbone" in both strands of DNA is not sufficient to produce a mutation. Since the molecules of chemical mutagens have to diffuse into the cell, it may be that their effects will be more localised in contrast to the random effects of radiations. Consequently, the reaction of two or three molecules with a small finite section of DNA may produce several breaks in close proximity to each other, thus permitting the inversion of small blocks of nucleotide pairs with the resultant production of mutations.

Both Auerbach (1946) and Altenburg and Browning (loc. cit.) have reported a high percentage of mosaicism following treatment of Drosophila with alkylating agents. Thus Altenburg and Browning found that following the injection of phenylalanine mustard, dimethyl myleran or 2, 5 bis-ethyleneiminohydroquinine, the percentage of fractionals detected varied from 30% to 67%, compared with about 7% for radiation induced mutations. Most of these fractionals appeared to be half mosaics, consequently alkylating agents may produce the major part of their effects in one or other of the DNA strands, but not in both. For example, Bautz and Freese (1960) have found that ethylation of the 7N position of guanine following treatment with ethylethane sulphonate resulted in the hydrolysis of the 9N sugar-base bond and the resultant loss of guanine. Subsequent substitution of adenine would lead to mutation. It was also found that methylation of guanine produced less hydrolysis of the 9N sugar-base bond and this may account for its weaker mutagenicity.

Perhaps a study of factors which modify chemical mutagenesis, and in particular influence recovery from premutational damage will help to clarify the nature of the initial damage produced by the alkylating agents and by other chemical mutagens and enable a comparison to be made between this damage and that produced by radiations. With this end in view, investigations have begun in this laboratory to test whether the frequency of mutations induced by the pyrrolizidine alkaloid heliotrine can be modified by those treatments which proved effective in modifying the radiation induced mutation frequency in *Drosophila*. Little is known at the molecular level about the nature of the mutagenic activity of the pyrrolizidine alkaloids. However, Clark (1960) has found that the replacement of a hydroxyl group with a methoxy group in the acid moiety of the molecule increases mutagenic activity, whilst the 1-2 double bond in the pyrrolizidine ring is also necessary for mutagenic activity. Clark (1959) has also found that the mutagenic activity is dependent on the whole molecule, since neither the acid nor basic moiety alone proved to be mutagenic. No data are present available on the occurrence of mosaics in *Drosophila* following treatment with pyrrolizidine alkaloids, but at least part of their action may involve both strands of DNA since it has been found that chromosome breaks are produced by the alkaloids.

To sum up, it is evident that a study of recovery from premutational damage will not only enable geneticists to determine the nature of this damage and the factors involved in its repair, but it will also enable a more effective comparison to be made of the steps involved in the production of radiation and chemically induced mutations. Also, investigations into the factors which influence recovery may be a step forward in the quest for directed mutation, whilst factors which modify mutagenic activity could have important practical implications in the treatment of cancer.

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# TASMANIAN SEA-CUCUMBERS (HOLOTHUROIDEA)

By

V. V. Hickman

(With two plates and 186 figures in the text.)

## ABSTRACT

Over five hundred and forty specimens of sea-cucumbers collected on the northern, eastern and southern coasts of Tasmania have been examined in the course of the present study. Seven families, 12 genera and 14 species are represented in the collection. One genus *Neoamphicyclus*, is regarded as new. Four species are also described as new, namely, *Psolidiella adhaerens, Neoamphicyclus lividus, Psolidium ravum* and *Paracaudina luticola.* Three other species have not been recorded previously from Tasmania but are known from the coast of Victoria. They are *Cucumella mutans* (Joshua), *Staurothyone inconspicua* (Bell) and *Trochodota roebucki* (Joshua). The total number of species now known to occur on the coast of Tasmania is 15. A description of each species is given.

## INTRODUCTION

The sea-cucumbers of Tasmania have received little attention from zoologists. The earliest reference to the occurrence of this group of marine animals in Tasmanian waters appears to be due to W. Saville-Kent, who exhibited some specimens from the Derwent Estuary at a meeting of this Society held on the 14th July, 1885. The specimens were dredged between Kangaroo Point and Ralphs Bay, At that time they were regarded as belonging to the genera *Synapta* and *Chirodota.* However, from the descriptions given by Saville-Kent, there is little doubt that the species exhibited were those now known as *Leptosynapta dolabrifera* (Stimpson) and *Trochodota allani* (Joshua), both of which are still frequently dredged in the locality mentioned.

No further reference to Tasmanian holothurians appears in the literature for over fifty years, in fact not until 1938, when H. L. Clark published a list of Tasmanian echinoderms. The list, which included seven holothurians, was based on specimens given to him by Professor T. T. Flynn, and on others collected during a dredging expedition in the Derwent Estuary on 15th November, 1929. The seven species listed by Clark (1938, p. 573) are the following:—

*Pentacta australis*
*Pseudocucumis thomsoni*
*Lipotrapeza vestiens*
*Stichopus mollis*
*Leptosynapta dolabrifera*
*Chiridota gigas*
*Trochodota allani*

Eight years later, when Clark (1946) published his comprehensive work on the echinoderm fauna of Australia, no further species were added to the list. However, he transferred *Pseudocucumis thomsoni* to a new genus *Mensamaria* and renamed it *Mensamaria thomsoni.*

In 1954 Heding and Panning, after examining some specimens dredged by Dr. Th. Mortensen in the eastern end of Bass Strait, stated that they agreed extremely well with Clark's examples of *Mensamaria thomsoni* from Tasmania. Moreover, Heding and Panning considered that *Mensamaria thomsoni* really belonged to the genus *Amphicyclus* Bell, and that it was a new species, which they therefore named *Amphicyclus mortenseni.*

In a table showing the distribution in Tasmania of animals, which he regarded as important intertidal species, E. R. Guiler (1954, p. 114) lists three of the seven holothurians recorded by Clark (1938) and adds *Paracaudina australis* (Semper).

The collection which forms the basis of the present study contains over 540 specimens taken on the northern, eastern and southern coasts of Tasmania. Most of them were found under stones at low tide, but some were taken by dredging. The specimens include representatives of all but one of the previously recorded species found in this State. One genus and four species appear to be new, whilst three other forms have not hitherto been found in Tasmanian waters, but are known from the coast of Victoria. The additions to the list of known Tasmanian species brings the number to 15 as follows:—

*Psolidiella adhaerens* sp. n.
*Staurothyone inconspicua* (Bell)
*Pentacta australis* (Ludwig)
*Cucumella mutans* (Joshua)
*Amphicyclus mortenseni* Heding and Panning
*Neoamphicyclus lividus* gen. et sp. n.
*Lipotrapeza vestiens* (Joshua)
*Psolidium ravum* sp. n.
*Stichopus mollis* (Hutton)
*Paracaudina australis* (Semper)
*Paracaudina luticola* sp. n.
*Leptosynapta dolabrifera* (Stimpson)
*Chiridota gigas* Dendy and Hindle
*Trochodota allani* (Joshua)
*Trochodota roebucki* Joshua

Since some of the previous records are founded on single specimens or on immature forms, it seemed desirable that, wherever possible, descriptions based on the new material available should

be given. In the case of *Amphicyclus mortenseni*, which is not represented in the collection, the description is based on accounts given by other authors.

Unless otherwise stated the specimens have been collected by the writer.

### Key to Species of Tasmanian Holothuroidea

1. Pedicels present .... 2
   Pedicels absent .... 10
2. Tentacles peltate .... *Stichopus mollis* (Hutton)
   Tentacles dendritic .... 3
3. Ten tentacles present .... 4
   More than ten tentacles persent .... 7
4. Body with a distinct creeping sole .... 5
   Body without a distinct creeping sole .... 6
5. Dorsal skin with crosses and scale-like plates .... *Psolidium ravum* sp. n.
   Dorsal skin without crosses and scale-like plates .... *Psolidiella adhaerens* sp. n.
6. Skin with small rods and large cruciform plates .... *Staurothyone inconspicua* (Bell)
   Skin with baskets and large buttons .... *Pentacta australis* (Ludwig)
7. Pedicels over whole body .... *Lipotrapeza vestiens* (Joshua)
   Pedicels not over whole body .... 8
8. Introvert with pedicels .... 9
   Introvert without pedicels .... *Amphicyclus mortenseni* Heding and Panning
9. Perforated plates with towers in skin .... *Cucumella mutans* (Joshua)
   Perforated plates without towers in skin .... *Neoamphicyclus lividus* gen. et sp. n.
10. Tentacles 15; body stout but tapering prosteriorly .. 11
    Tentacles 10-12; body slender and cylindrical .... 12
11. Skin with numerous crossed cups .... *Paracaudina luticola* sp. n.
    Skin with perforated irregular plates .... *Paracaudina australis* (Semper)
12. Skin with anchors .... *Leptosynapta dolabrifera* (Stimson)
    Skin with wheels .... 13
13. Wheels grouped in papillae .... *Chiridota gigas* Dendy and Hindle
    Wheels not grouped in papillae .... 14
14. Tentacles with four digits .... *Trochodota roebucki* Joshua
    Tentacles with eight to ten digits .... *Trochodota allani* (Joshua)

## Order: DENDROCHIROTA

### Family: CUCUMARIIDAE

### Genus: **PSOLIDIELLA** Mortensen, 1925

### *Psolidiella adhaerens* sp. n.

(Pl. I, fig. 1 and text-figs. 1-16)

The living animal is usually light fawn in colour, some specimens being almost white. The tentacles are white or yellowish brown and marked with golden brown spots. Foreign particles such as shell grit, sponge spicules, sand grains and pieces of seaweed often adhere to the dorsal surface and sides of the holothurian tending to conceal it.

When fully extended the largest specimens measure about 37.0 mm. in length and 9.0 mm. in greatest width. The anterior and posterior ends of the body are directed upwards. The dorsal surface and sides generally exhibit a number of longitudinal ridges. The ventral surface forms a distinct sole by means of which the animal is firmly attached to the stone or shell on which it is resting.

The tentacles are ten in number. They are dendritic and the ventral pair smaller than the others. The mouth aperture is surrounded by papillae. The introvert is short.

The pedicels are well developed round the margin of the sole, where they are arranged in three rows. They are also present in two or three rows on the mid ventral radius within the sole. The region between the margin of the sole and the mid ventral radius is devoid of pedicels. Beyond the margin of the sole, on the sides and dorsal surface of the body, are numerous pedicels, which are scattered irregularly. They are generally longer and more slender than those round the margin of the sole. They are completely retractile and their main function seems to be the attaching of the numerous foreign particles with which the holothurian is often covered. Pedicels are absent from the introvert.

Calcareous particles or spicules are present in the skin of the body wall, the introvert, and tentacles. They are absent from the peristome and oral papillae.

The spicules of the body wall are largest and most numerous in the soft interradial skin of the sole. Here they have the form of perforated plates (text-figs. 1-5), the larger ones measuring 160-210$\mu$ in greatest diameter and possessing from 11-18 holes. On the sides and dorsal surface spicules are much less numerous and smaller, the larger ones being 135-153$\mu$ in maximum diameter and perforated by 5-7 holes (text-figs. 6-9).

In the skin of the introvert the spicules are very small, 27-33$\mu$ in length and have the form of branched rods with nodular projections (text-figs. 10-13).

In the tentacles the spicules are very large. They have the form of irregular perforated rods and bars measuring 210-405$\mu$ in length. They are disposed transversely to the long axis of the stem or branch of the tentacle (text-figs. 14-15).

The pedicels are devoid of spicules except for the perforated disk in the sucker. The disk is large and strongly developed in the pedicels of the sole but smaller and somewhat degenerate in those of the rest of the body.

The calcareous ring surrounding the oesophagus is composed of five radial and five interradial

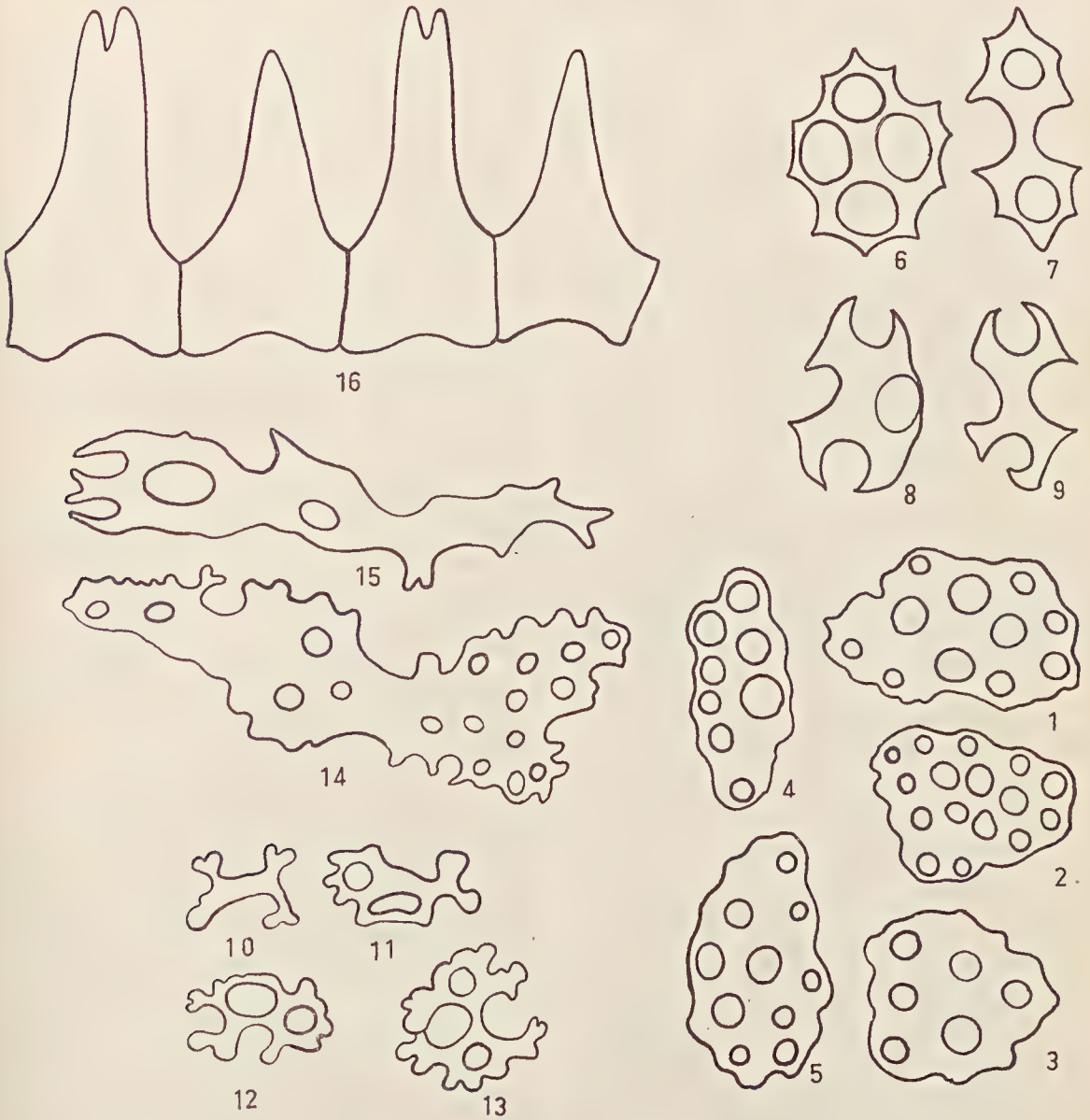
ossicles. They are devoid of posterior prolongations (text-fig. 16). Both the radials and interradials are somewhat pointed anteriorly, but the narrow end of the radials is notched.

The anal aperture is surrounded by five anal teeth.

The oesophagus is short and relatively narrow without any bulbous enlargement. The intestine has the usual S-like curvature and the mesentery supporting its posterior end lies in the left ventral interradius. The cloaca is moderately large.

The respiratory trees or water lungs on each side extend from the cloaca as far forward as the vascular ring and are well branched.

The five radial muscles of the body are well developed as also are the five retractor muscles.




*Psolidiclla adhaerens* sp. n.

FIGS. 1-5.—Perforated plates from sole. FIGS. 6-9.—Perforated plates from sides and dorsum. FIGS. 10-13.—Spicules from introvert. FIGS. 14-15.—Perforated bars from tentacles. FIG. 16.—Four ossicles from calcareous ring.

The latter are long being attached posteriorly slightly behind the middle of the body.

The vascular ring gives rise ventrally to a single large Polian vesicle. From the dorsal side of the ring a coiled stone canal ending in a madreporite is given off and lies in the dorsal mesentery.

The gonads are situated dorsally near the middle of the body. The genital duct runs forward in the dorsal mesentery and opens between the bases of the two dorsal tentacles. In the male the testis has the form of about 80 pale yellow slender tubules arranged in a group of 40 on each side of the mesentery. Only a few of the tubules are branched. In the female the ovary is composed of about 36 finger-like lobes, 18 on each side of the mesentery. Mature ova are large, measuring 548$\mu$ long and 493$\mu$ wide. They have a bluish-grey colour.

*Locality*: Pirates Bay, Eaglehawk Neck, Tasmania. Two specimens were collected on 19th March, 1954, seventy-five on 13th May, 1954, and four on 9th March, 1960.

All the specimens were found under stones near low tide level. The holothurian seems to favour stones that are cemented together by encrusting sponges and other organisms. When once established in a suitable position it adheres very firmly and does not readily move from its position. A specimen kept in an aquarium in the laboratory remained fixed in the one place for more than seven days, although the conditions under which it was living were by no means normal.

*Affinities*: *Psolidiella adhaerens* is close to the New Zealand species, *Psolidiella nigra* Mortensen (1925), but differs in colour, in possessing anal teeth and in lacking spicules in the walls of the pedicels. Panning (1949) has transferred *Thyone spectabilis* Ludwig and *Pseudocolochirus mollis* Ludwig & Heding to the genus *Psolidiella*. The former has an almost globular body with rod-like spicules in the skin and the latter exhibits atrophy of the calcarious particles. In these and other characters they differ from the Tasmanian species.

Genus: **STAUROTHYONE** H. L. Clark, 1938.

*Staurothyone inconspicua* (Bell).

(Pl. I, fig. 2 and text-figs. 17-23.)

*Cucumaria inconspicua Bell*, 1887.
" " Joshua, 1914.
*Staurothyone inconspicua* Clark, 1938.
" " Clark, 1946.
" " Panning, 1949.

This species has not been previously recorded from Tasmania, but it has been found on the coast of Victoria and South Australia. Both Clark (1938) and Panning (1949) think that the species may be the same as *Staurothyone rosacea* (Semper) from Aden.

The Tasmanian species have been preserved in alcohol without previous narcotization and nearly all of them are strongly contracted. The largest measures 25.0 mm. long and 12.0 mm. wide in the contracted condition. A single specimen with the tentacles extended is 38.0 mm. long and 8.00 mm. wide. The body is somewhat narrowed posteriorly and in preserved specimens is curved upwards at the anterior and posterior ends.

The colour of the body, tentacles and pedicels varies from dark-brown to greyish-brown.

There are ten tentacles. They are dendritic and the ventral pair slightly smaller than the others. The mouth aperture is not surrounded by papillae and the introvert is short.

Pedicels occur on all five radii. On the two dorsal radii they are small and arranged in about two rows. On the three ventral radii they are larger and more numerous, forming three or four rows near the middle of the body but decreasing to two rows anteriorly and posteriorly. A few pedicels extend onto the introvert. Some scattered pedicels are also present on all interadii but are more numerous dorsally than ventrally.

Calcareous particles or spicules are present in the skin of the body-wall, tentacles, peristome, introvert and pedicels.

The spicules of the body-wall have the form of small rods bluntly forked at each end and often with one or more lateral projections (text-figs. 17-20). These small rods are usually 45-54 $\mu$ in length. In addition to these small rods there is a slightly deeper layer of large crosses which measure 170-204 $\mu$ in length and 96-138 $\mu$ in width. The arms of the cross are usually forked twice and end in bluntly rounded projections (text-fig. 21).

In the tentacles the spicules are slender rods, 39-93$\mu$ in length and having bluntly forkel ends (text-fig. 22). In the peristome, introvert and sides of the pedicels the spicules have the form of short rods similar to those in the body-wall but much smaller, being only 18-36$\mu$ in length.

The calcareous ring is composed of five radial and five interradial ossicles, which are fused together. There are no posterior projections or tails. The ossicles are short and each is excavated on the posterior margin. Anteriorly each is produced into a narrow point, which is notched in the case of the radials but not notched in the interradials (text-fig. 23).

Surrounding the anal aperture are five anal teeth, which are radial in position.

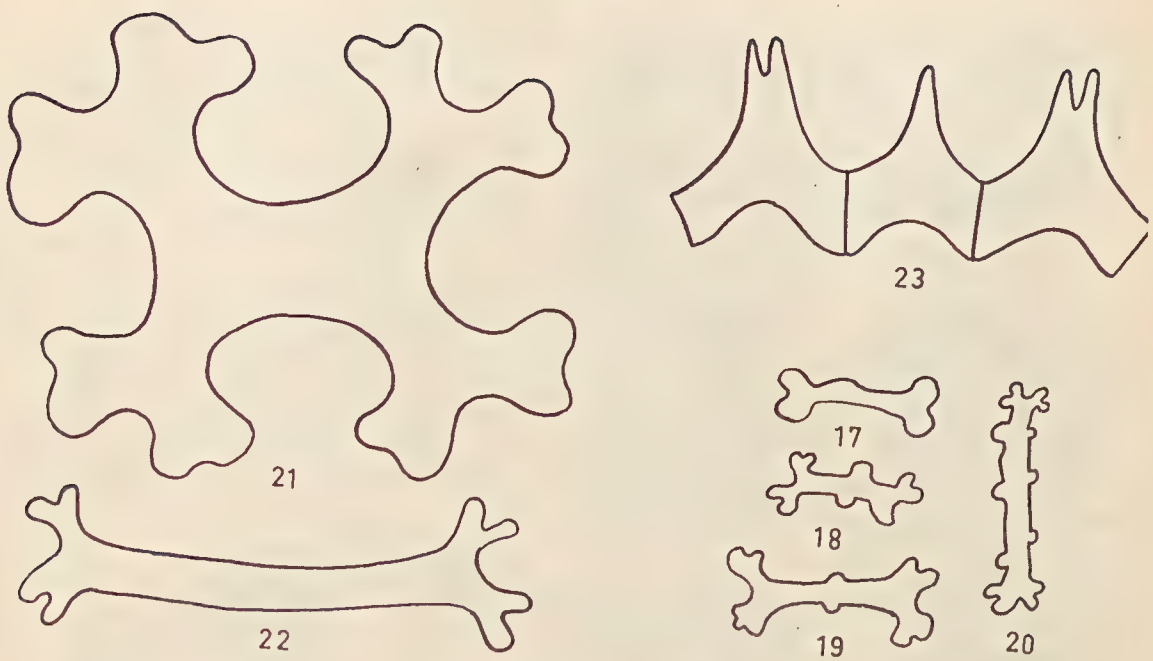
The oesophagus is short and narrow without any enlargement.

The respiratory trees are well developed and strongly branched.

Of the five radial muscles of the body-wall, the three ventral bands are larger than the two dorsal bands. The posterior ends of the retractor muscles are inserted slightly in front of the middle of the body.

The vascular ring is connected dorsally with a single stone canal and madreporite, and ventrally with two Polian vesicles.

*Localities*: Four specimens were collected by A. M. Olsen at East Devonport in January, 1940, and six specimens by J. L. Hickman near First Lookout Point, Cockle Creek, 3rd December, 1952. All the specimens were found under stones near low tide mark.




*Staurothyone inconspicua* (Bell).

FIGS. 17-20.—Rods from outer layer of body-wall. FIG. 21.—Large cross from deeper layer of body-wall. FIG. 22.—Spicule from a tentacle. FIG. 23.—Three ossicles from the calcareous ring.

Genus: **PENTACTA** G .A. Goldfuss, 1820.

*Pentacta australis* (Ludwig).

(Pl. I, fig. 3 and text-figs. 24-37.)

*Colochirus australis* Ludwig, 1874.
*Colochirus doliolum* Erwe, 1913.
" " Ekman, 1918.
*Pentacta australis* Clark, 1932.
" " Clark, 1938.
" " Clark, 1946.
*Colochirus australis* Panning, 1949.

The recorded occurrence of this species in Tasmanian waters is based on a single very young specimen dredged from D'Entrecasteaux Channel by T. T. Flynn and identified by H. L. Clark (1938). The specimen was bright brown with large yellow brown pedicels and Clark remarks "No other specimen of this colour or with such large pedicels has been seen, but there is no evident reason for doubting the identification". The species occurs at many places on the Australian coast from Western Australia to Queensland.

In the present collection there are eight specimens from the Derwent Estuary. With tentacles extended they vary in length from 10.0 - 27.0 mm. and in width from 3.0 - 5.0 mm.

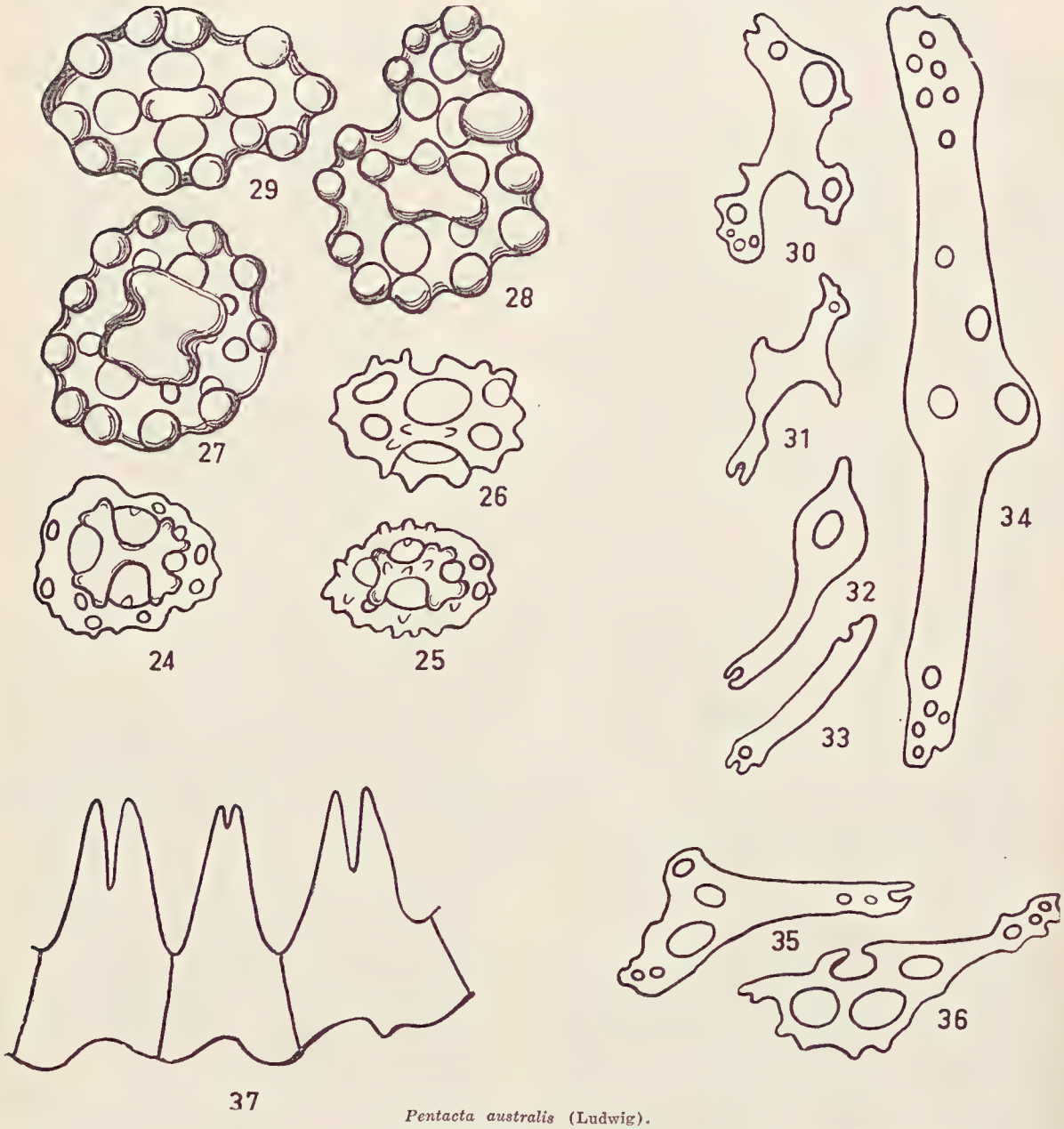
The general body colour in life is orange and white. The pedicels are orange with darker orange patches around their bases. The tentacles have dark-stems stems with pale-brown translucent pinnae. The ventral surface is mainly white with a few small patches of orange. In alcohol specimens are bleached white except for the tentacles, which retain their brown colouration.

In extended specimens the body is somewhat quadrangular in transverse section and tapers slightly towards the posterior end. Ten tentacles are present, the ventral pair being smaller than the others. The mouth aperture is surrounded by papillae. Between the bases of the tentacles are large calcareous bodies. which appear as ten conspicuous white patches around the outer margin of the peristome.

The body-wall is more or less rigid due to the abundant calcareous particles present. Each radius tends to form a ridge along which the pedicels project. The base of each pedicel is surrounded by a tubercle and at the anterior end of each radius a peg-like process projects forward over the introvert. The pedicels are arranged in two loose rows on each radius and are more numerous on the three ventral radii than on the two dorsal radii.

Calcareous particles or spicules are very numerous and are present in the skin of the body-wall, tentacles and pedicels.

In the body-wall the spicules form two more or less distinct layers. The spicules of the outer layer are in the form of small oval "baskets" about 42-70$\mu$ in length (text-figs. 24-26). They are furnished with a well-developed primary cross, which surmounts a perforated plate having a number of projections. Below the "baskets" is an inner layer of large buttons, more or less oval in shape and composed of many reticulate strata.




*Pentacta australis* (Ludwig).

FIGS. 24-26.—Baskets form outer layer of body-wall. FIGS. 27-29.—Knobbed perforated plates from body-wall. FIGS. 30-34.—Perforated rods and plates from tentacles. FIGS. 35-36.—Perforated plates from pedicels. FIG. 37.—Three ossicles from the calcareous ring.

Most of the buttons are about 420$\mu$ in length but some of the largest are 840$\mu$. Intermingled with the large buttons are smaller perforated plates. 70-84$\mu$ in length and furnished above and below with rounded knobs or nodules (text-figs. 27-29).

The tentacles are supported by slightly curved perforated rods and plates of irregular form (text-figs. 30-34). The rods are arranged transversely. Those towards the bases of the tentacles are larger than the others and measure about 420$\mu$ in length.

The pedicels possess numerous "baskets" and irregular perforated plates and rods (text-figs. 35-36). The "baskets" are similar to those in the body-wall and measure 21-60$\mu$ in length.

The calcareous ring is simple and without posterior forked tails (text-fig. 37). The radials are narrow and pointed anteriorly, the point being

cleft. The interradials are similar but somewhat smaller and the point not so deeply cleft. The posterior margin of the ring is undulating.

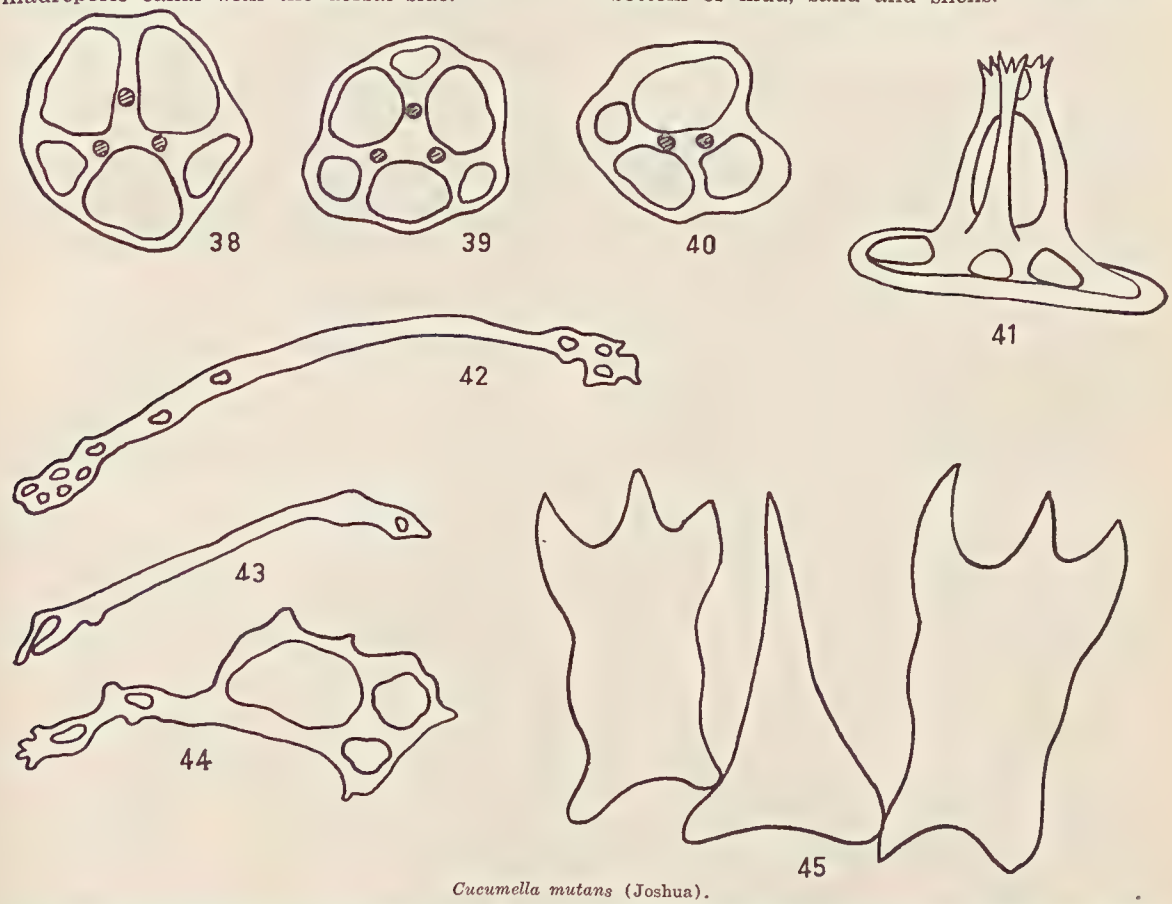
The respiratory trees extend forward from the cloaca for about half the length of the body and have about eight branches.

The five retractor muscles have their posterior ends inserted near the mid length of the body.

A single large Polian vesicle is connected with the ventral side of the vascular ring and a single madreporic canal with the dorsal side.

The gonad is situated dorsally in the anterior third of the body. In a female specimen it consists of 28 short finger-like caeca, about 14 on each side of the dorsal mesentary. Some of the caeca contain large eggs measuring 0.47 mm. long and 0.42 mm. wide.

*Localities*: One specimen was taken in the Derwent Estuary off Sandy Bay, 23rd September, 1955; and seven at Ralphs Bay, 30th June, 1959. All were dredged at a depth of 4-6 fathoms on a bottom of mud, sand and shells.




*Cucumella mutans* (Joshua).

FIGS. 38-40.—Perforated basal plates of tables. FIG. 41.—Table with tower of three columns in side view. FIGS. 42-44.—Perforated rods from tentacles. FIG. 45.—Three ossicles from the calcareous ring.

Family: PHYLLOPHORIDAE.

Genus: **CUCUMELLA** Ludwig & Heding, 1935.

*Cucumella mutans* (Joshua).

(Pl. I, fig. 4 and text-figs. 38-45.)

*Cucumaria mutans* Joshua, 1914.
" " Joshua & Creed, 1915.
" " Clark, 1938.
*Cucumella mutans* Heding & Panning, 1954.

This species has not been recorded from Tasmania hitherto, but is known from the coasts of Victoria, South Australia and Western Australia. The present collection contains specimens from the Derwent Estuary.

A well extended specimen measures 50.0 mm. long and 10.0 mm. in greatest width. It has the form shown in Pl. I, fig. 4.

The general colour of the body is brownish with the tentacles darker and pedicels lighter. Small specimens have a bluish tinge, especially on the introvert.

In Victorian specimens Joshua (1914) gives the number of tentacles as 10, but Heding and Panning (1954) state that " judging from his excellent figure

of the calcareous ring it could be 20". In Tasmanian specimens the number is 25. They are arranged in one circle and there is a tendency for 2 large tentacles to be situated in each interradius and 3 smaller ones in each radius.

The pedicels are confined to the radii and do not extend into the interradii. Anteriorly and posteriorily in each radius they are arranged in two rows, but near the middle of the body they are in more than two rows, especially in the ventral radius where four or five rows may be present. Towards the front the pedicels extend onto the introvert and here they are longer and more slender than elsewhere.

Calcareous particles or spicules are numerous and are present in the skin of the body-wall, introvert, peristome, tentacles and pedicels.

The spicules of the body-wall, introvert and pedicels are in the form of tables with a short spire or tower. The diameter of the tables measures up to 105$\mu$ and the height of the spire is from one half to three quarters the diameter of the table. Most of the spires have three columns but some only two. The apex of the spire is provided with six or seven sharp spines. The tables have from four to twenty-one perforations (text-figs. 38-41).

In the skin of the peristome, tentacles and the slender pedicels of the introvert some of the spicules have the form of curved bars or rods with flat perforated ends. They measure up to 186$\mu$ in length. Many of the rods are branched in an irregular manner (text-figs. 42-44).

All the pedicels have the usual perforated plate in the suctorial end.

The calcareous ring is composed of five radial and five interradial ossicles. The radials are wide distally and furnished with three points as shown in text-fig. 45. The interradials are slender and pointed at the apex but expanded towards the base. Posterior forked tails are absent.

The oesophagus is expanded into a bulb at its posterior end.

The respiratory trees are well developed and extend from the cloaca almost to the vascular ring.

The retractor muscles are long and their posterior ends attached near the mid length of the body.

Four or five Polian vesicles open into the vascular ring, the largest being ventral and almost as long as the oesophagus.

Two large coiled madreporic canals open into the dorsal part of the vascular ring.

In a male specimen, which was dissected, the testes are situated dorsally near the middle of the body. They are made up of about 75 primary tubules on each side of the dorsal mesentery. Most of the tubules are unbranched but a few are branched. They occupy a large part of the body cavity.

*Localities*: Two specimens taken in the Derwent Estuary off Sandy Bay, 23rd September, 1955. One at Ralphs Bay, 29th August, 1955, and four at the same locality, 28th August, 1959. All were dredged in about 5-7 fathoms by J. L. Hickman.

## Genus: **AMPHICYCLUS** Bell, 1884.

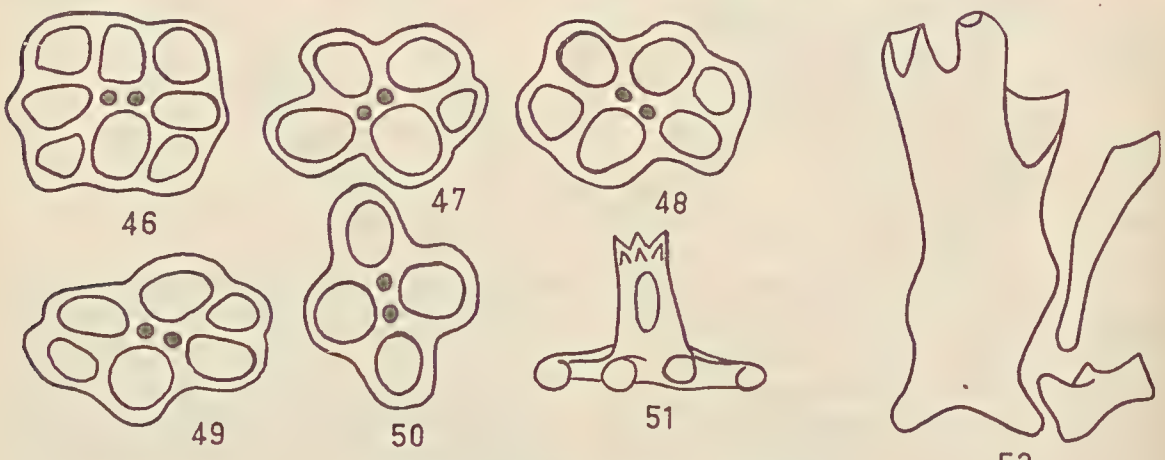
*Amphicyclus mortenseni* Heding & Panning.

(Text-figs. 46-52.)

*Pseudocucumis thomsoni* Clark, 1938.
*Mensamaria thomsoni* Clark, 1946.
*Amphicyclus mortenseni* Heding & Panning, 1954.

This species, first recorded from Tasmania by Clark (1938), does not appear to be represented in the present collection. The following description is therefore based on the accounts given by Clark (1938) and Heding & Panning (1954).

The slender, nearly cylindrical body is pale-grey or pale-yellow in colour. It measures up to 90.0 mm. long and 10.0 mm. wide.




*Amphicyclus mortenseni* Heding & Panning.

(Figures after Heding & Panning, 1954.)

FIGS. 46-50.—Perforated basal plates of tables from introvert. FIG. 51.—Table with tower of two columns in side view. FIG. 52.—Two ossicles from calcareous ring.

According to Clark three of his specimens had 24, 23 and 20 tentacles respectively. Heding & Panning describe the number of tentacles as 25, arranged in an outer circle of 15 and an inner circle of 10.

The pedicels are usually in two rows, occasionally in three, on the radii. The introvert is white and without pedicels.

Calcareous particles or spicules are absent from the skin of the body-wall and from the wall of the pedicels, but present in the introvert and tentacles.

In the introvert the spicules have a basal plate perforated with 4-6 holes and surmounted by a two-columned tower with a strongly spined apex (text-figs. 46-51).

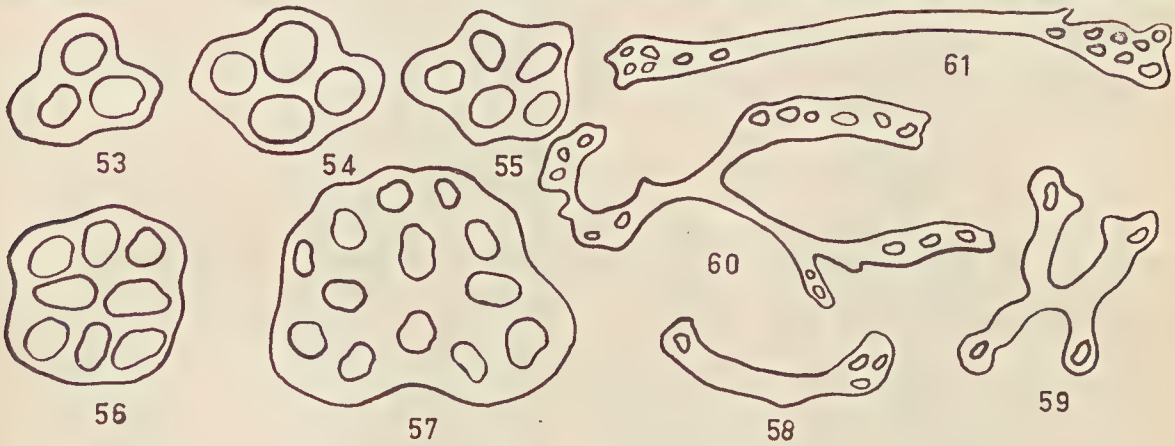
The spicules of the tentacles are in the form of rods.

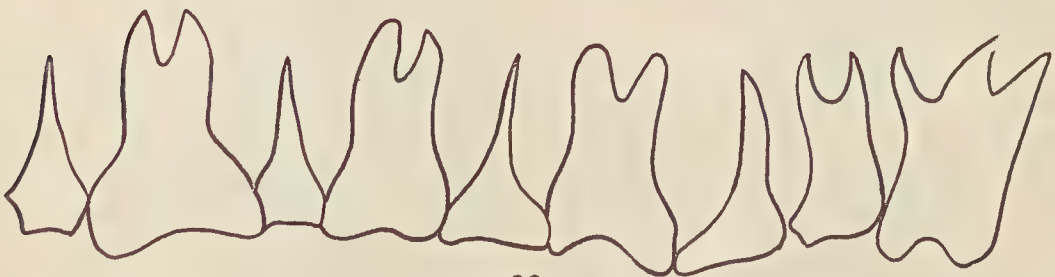
The calcareous ring is simple and devoid of forked tails. The radials have two small and one large insertion point for the radial tentacles. The vascular notch is large. The interradials have a narrow anterior part, which is not fused with the broader base (text-fig. 52).

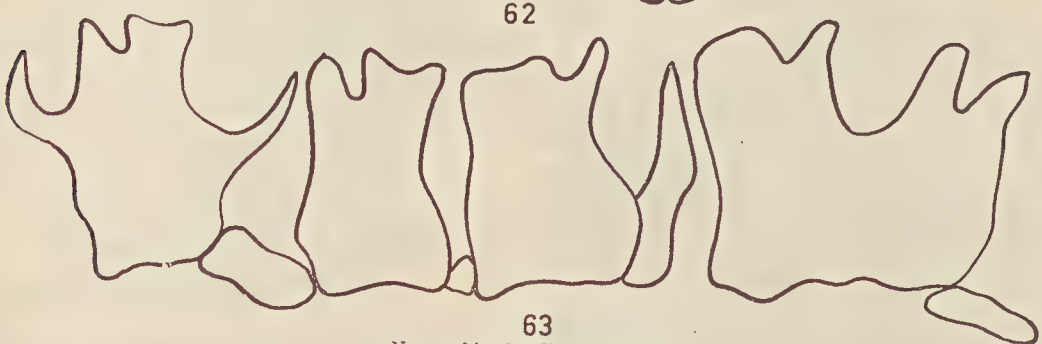
The respiratory trees are well developed but have few branches.

The retractor muscles are very long. Two Polian vesicles and a single stone canal are present. The gonads are slightly branched and lie far back in the body.

*Locality*: D'Entrecasteaux Channel at five fathoms, two specimens collected by T. T. Flynn (*vide*




*Neoamphicyclus lividus* sp. n.

FIGS. 53-57.—Perforated plates from body-wall. FIGS. 58-59.—Rods from tentacles. FIGS. 60-61.—Rods from papillae of peristome. FIG. 62.—Calcareous ring (opened out) showing fusion of one of the radials with an interradial. FIG. 63.—A markedly abnormal calcareous ring (opened out) showing extensive fusion of parts.

Clark, 1938). Eastern end of Bass Strait at 70-260 fathoms, twenty-two specimens collected by T. Mortensen (*vide* Heding & Panning, 1954).

### Genus: **NEOAMPHICYCLUS** gen. nov.

*Diagnosis*: Dendrochirote holothurians with 25 tentacles arranged in two circles. Pedicels on radii but lacking on interradii. The pedicels extend onto the introvert. Calcareous ring simple without posterior bipartite prolongations. The interradialia somewhat reduced. In adults the calcareous bodies or spicules are few and widely scattered in the body-wall, where they have the form of perforated plates without towers or spires. Spicules are absent from the pedicels, except for the end plate.

Genotype: *Neoamphicyclus lividus* sp. n.

This genus appears to be closely related to *Amphicyclus* Bell, but differs in having pedicels on the introvert and in lacking spires or towers on the calcareous bodies.

### *Neoamphicyclus lividus* sp. n.

(Pl. I, fig. 5 and text-figs. 53-63.)

This species is one of the most common Tasmanian holothurians and the present collection contains more than 150 specimens. Nearly all of them are slaty-blue in colour with the tentacles and introvert usually darker. In some the tentacles and posterior end of the body are dark-blue.

The largest specimen when extended measures 110 mm. long and 10 mm. wide. Most specimens, however, do not exceed 80-90 mm. in length.

The 25 tentacles are dendritic. They are arranged in two circles, an outer circle of 15 large tentacles and an inner of 10 smaller ones. The outer tentacles occur three in each interradius and the inner ones two in each radius.

The pedicels are on the radii but not on the interradii. They are usually in two rows, but on the ventral radii in some specimens three rows are present. Long slender pedicels are present on the introvert.

Calcareous particles or spicules are present in the skin of the body-wall, the tentacles, the papillae surrounding the mouth and, in the case of young specimens, in the skin of the introvert. Apart from the end plate they are absent from the pedicels. In most cases the spicules of the body-wall are few and well scattered. They are more numerous near the middle of the body than they are anteriorly or posteriorly. In three large specimens they are absent from the skin of the introvert. In other cases, however, a few scattered spicules are present.

The particles from the body-wall have the form of perforated plates up to 54$\mu$ in diameter. The number of perforations varies from three to eight, but is usually four or five (text-figs. 53-57). In small specimens, about 8.0 mm. long, the plates are more numerous and larger, some of the larger plates measuring 96$\mu$ in diameter and having eleven perforations. In no specimen, either young or adult, is there any evidence of the presence of a spire or tower on the plates.

In the tentacles the spicules have the form of curved rods up to 195$\mu$ in length. The rods have perforated ends and are sometimes branched (text-figs. 58-59).

In the papillae of the peristome there are curved rods similar to those of the tentacles and in addition many rods with perforated branches (text-figs. 60-61).

The calcareous ring usually has five radial and five interradial ossicles. The radials are wide with a deep notch and three points of insertion for the tentacles in front. Posteriorly they are deeply excavated. The interradials are very slender and slightly constricted, so that they form a narrow union with the wider posterior part, which is excavated on its hinder margin (text-fig. 62). In a number of cases abnormal conditions occur in which the radials become partly or wholly fused with the interradials, so that the ring appears to have a reduced number of segments (text-fig. 63).

The oesophagus is about one-eighth the length of the extended body. It has a bulbous muscular region near the middle of its length. The intestine exhibits the usual contortion. In the living animal the stomach or mid-gut region is brown. The cloaca is darkly pigmented. The posterior end of the intestine is supported by the mesentery in the left ventral interradius.

The respiratory trees are well developed and extend forward almost to the vascular ring.

The retractor muscles are long and attached posteriorly slightly behind the middle of the body.

The ring vessel is provided with from two to five Polian vesicles. A single coiled madreporic canal opens into the dorsal part of the ring vessel.

The gonads are situated dorsally near the middle of the body. In the male the testes are pale cream in colour and made up of about 100 slender tubules, 50 on each side of the dorsal mesentery. A few of the tubes branch. In the female the ovary is small and has about 15 finger-like lobes on each side of the dorsal mesentery. The mature ovum measures 350$\mu$ in diameter.

*Localities*: Coal Point, Bruny Island; January, 1937, 5 specimens. East Devonport; January, 1940, 13 specimens collected by A. M. Olsen. Recherche Bay, Catamaran; 3rd December, 1952, 18 specimens. Pirates Bay, Eaglehawk Neck; 19th March, 1954, 70 specimens; 13th May, 1954, 40 specimens; 22nd May, 1959, 4 specimens; and 7th March, 1960, 17 specimens collected by J. L. Hickman and the author. All the specimens were found under stones near low tide mark.

I formerly regarded *Neoamphicyclus lividus* sp. n. as being *Mensamaria thomsoni* Clark (1946) and gave it this name in designating it as the host of the turbellarian, *Notothrix inquilina*, which is frequently present in its gut (Hickman, 1955).

### Genus: **LIPOTRAPEZA H. L. Clark**, 1938.

*Lipotrapeza vestiens* (Joshua).

(Pl. I, fig. 6 and text-figs. 64-74.)

*Phyllophorus vestiens* Joshua, 1914.
*Lipotrapeza vestiens Clark* 1938.
" " Clark, 1946.
" " Heding & Panning, 1954.

A single specimen of this holothurian was found at low tide at Wynyard by Professor T. T. Flynn

and recorded by H. L. Clark (1938). The species has also been found on the coasts of Western Australia and Victoria.

The present collection contains two specimens taken near Burnie. Both are strongly contracted and have the tentacles withdrawn. One measures 84 mm. long and 23 mm. wide, the other 52 mm. long and 19 mm. wide. They are fusiform in shape and exhibit a distinct dorsal curvature. Joshua (1914) has pointed out that this flexure occurs in preserved specimens but not in the living holothurian.

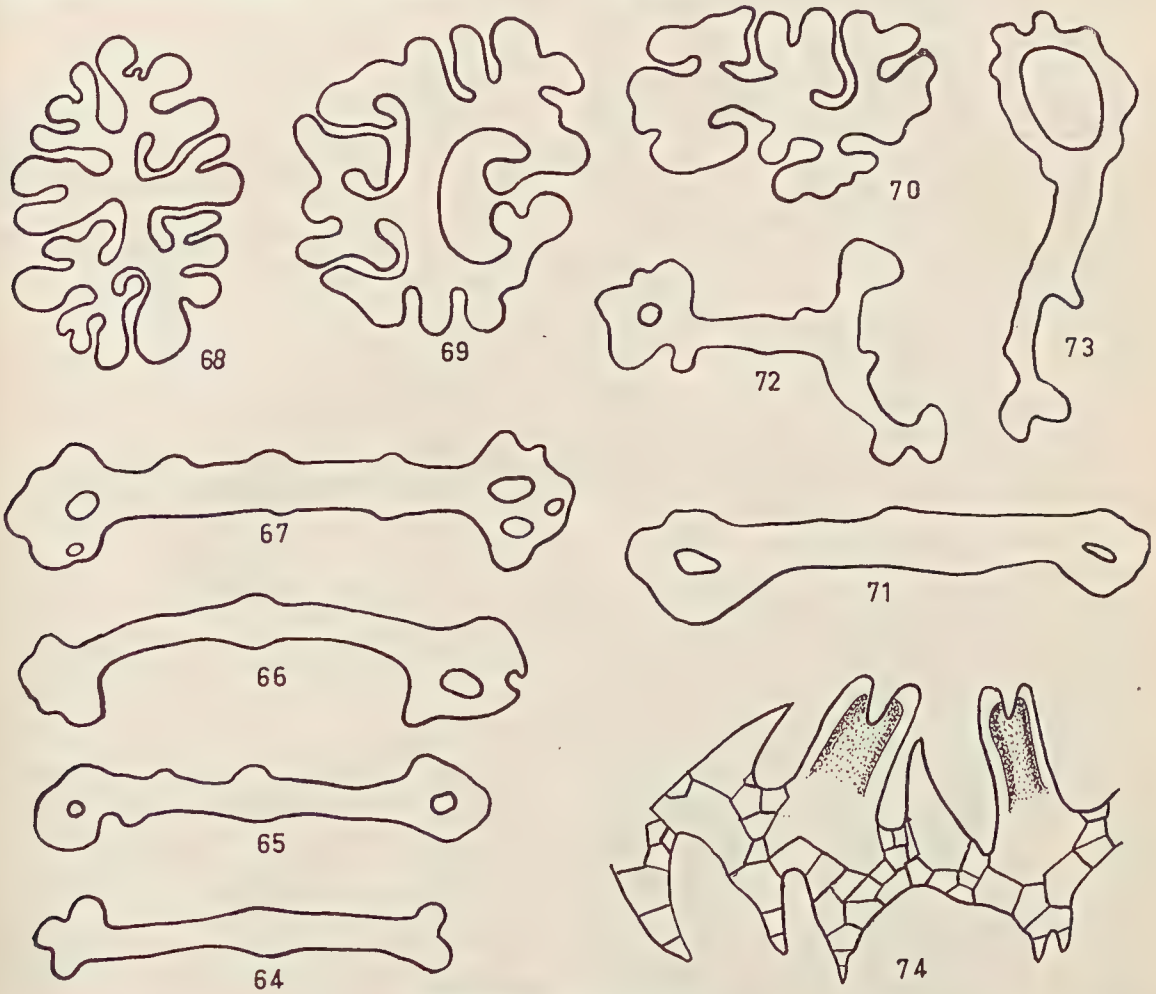
The general body colour is light-brown with the pedicels white and the tentacles black.

Twenty tentacles are present. They are ranged in an outer circle of ten and an inner circle of ten. Those of the inner circle are smaller than the others and are disposed in five pairs.

The body-wall is thick and very muscular. The pedicels are numerous, not arranged in rows, but scattered thickly over the whole surface of the body.

Calcareous particles or spicules are absent from the body-wall but are present in the tentacles, peristome, introvert and the anal region. The pedicels have the usual perforated end plate but no other calcareous bodies.

In the parts of the body where they occur the spicules have the form of rods and rosettes (foliaceous spicules). In the tentacles the rods measure up to 114$\mu$ in length and often have expanded perforated ends (text-figs. 64-67). The rosettes vary in form (text-figs. 68-70). In the main stems of the tentacles and also in the peristome they are frequently grouped together in large numbers forming heaped-up masses, which may also include a few rods.




*Lipotrapeza vestiens* (Joshua).

FIGS. 64-67.—Rods from tentacles. FIGS. 68-70.—Rosettes from main stem of tentacle. FIGS. 71-73.—Rods from introvert. FIG. 74.—Four ossicles from calcareous ring.

In the introvert rods are more numerous than rosettes. They measure up to 69μ in length and are sometimes branched (text-figs. 71-73).

The skin around the anal aperture is furnished with a few small rosettes. Tables, which Clark (1938) found in the anal region of one of his small specimens, do not appear to be present.

The calcareous ring has five radial and five interradial ossicles. The radials are wide, deeply notched in front, and strongly concave on the outer surface. The base of each is divided into a number of angular pieces and forms a pair of short posterior projections of variable length. The interradials are narrow and pointed in front. Like the radials they have a base made up of a number of angular pieces, but without posterior projections, the posterior margin being concave (text-fig. 74).

The intestine has the usual S-shaped curvature and its final loop is supported by the mesentery attached to the midventral radial muscle band. The respiratory trees are extensive and well branched.

The five retractor muscles are short, their posterior ends being inserted anterior to the gonad.

One Polian vesicle is present in the smaller specimen and two in the larger. They arise from the ventral part of the vascular ring.

The gonads are situated dorsally near the middle of the body. They have the form of numerous unbranched tubules which open separately into the gonoduct and are disposed on each side of the dorsal mesentery. In the smaller specimen, a male, the testis is composed of 275 such tubules. In the larger specimen, a female, the ovary is formed of 290 tubules. Mature ova measure about 0.53 x 0.49 mm. In both sexes the gonad is pale-yellow in colour.

*Locality*: Cooee, Burnie, North West Tasmania; two specimens collected by Mr. D. J. Cullen of the Burnie High School. The specimens were taken at low tide level and were buried in sediments of mud, sand and small pebbles, occurring between groups of quartzite rock in the infra-littoral zone.

### Family: PSOLIDAE.

The family Psolidae contains a small number of holothurians characterised chiefly by the possession of a distinct thin-walled sole on the ventral surface and by having the dorsal side more or less completely covered by scales. Another feature to which some importance has been given is the position of the third mesentery, that attaches the last loop of the intestine to the body-wall. However, statements in reference to this feature appear contradictory. Deichmann (1941, p. 73) says "The Cucumariidae seem typically to have the third mesentery attached on the right side of the midventral muscle band, the Phyllophoridae seem to have it attached to the left, and the Psolidae have it either way". Mortensen (1925, p. 359), however, states that the Cucumariidae have the hind part of the intestine attached in the left ventral interradius and the Psolidae have it in the right. Moreover. Mortensen examined the type of the genus *Psolidium*, namely *Psolidium dorsipes* Ludwig, and found that "beyond doubt the posterior part of the intestine really lies in the right ventral interradius". Deichmann (1941, p. 135), on the other hand, states that in the genus *Psolidium*, the third loop of the intestine is attached in the left ventral interradius.

In the species described in the present paper the posterior loop of the intestine is attached in the right ventral interradius.

### Genus: **PSOLIDIUM** Ludwig 1886.

*Psolidium ravum* sp. n.

(Pl. II, fig. 7 and text-figs. 75-86.)

The body measures 30 mm. long and 10 mm. wide. The anterior end is narrow and cylindrical; the posterior end short and conical. In the living animal both ends are directed upwards. The dorsal surface is wrinkled longitudinally. The ventral surface has a well delimited sole, which measures about 25 mm. long and occupies a large part of the under side.

The colour in alcohol is grey, the sole being lighter with a brownish tinge. The introvert and tentacles are dark-grey. The ends of the tentacles and pedicels are white.

The body-wall is thick and tough except on the sole, where it is thin. Scales are evident externally only around the conical posterior end and anal aperture. Elsewhere they are sunk below the surface.

Ten tentacles are present, the ventral pair being much smaller than the others. The mouth aperture is surrounded by papillae.

Pedicels are scattered irregularly on the dorsal surface but are not present on the introvert. On the ventral side they are large and arranged in three or four rows around the margin of the sole and in two rows on the midventral radius bisecting the sole. They are not present on the ventral interradii.

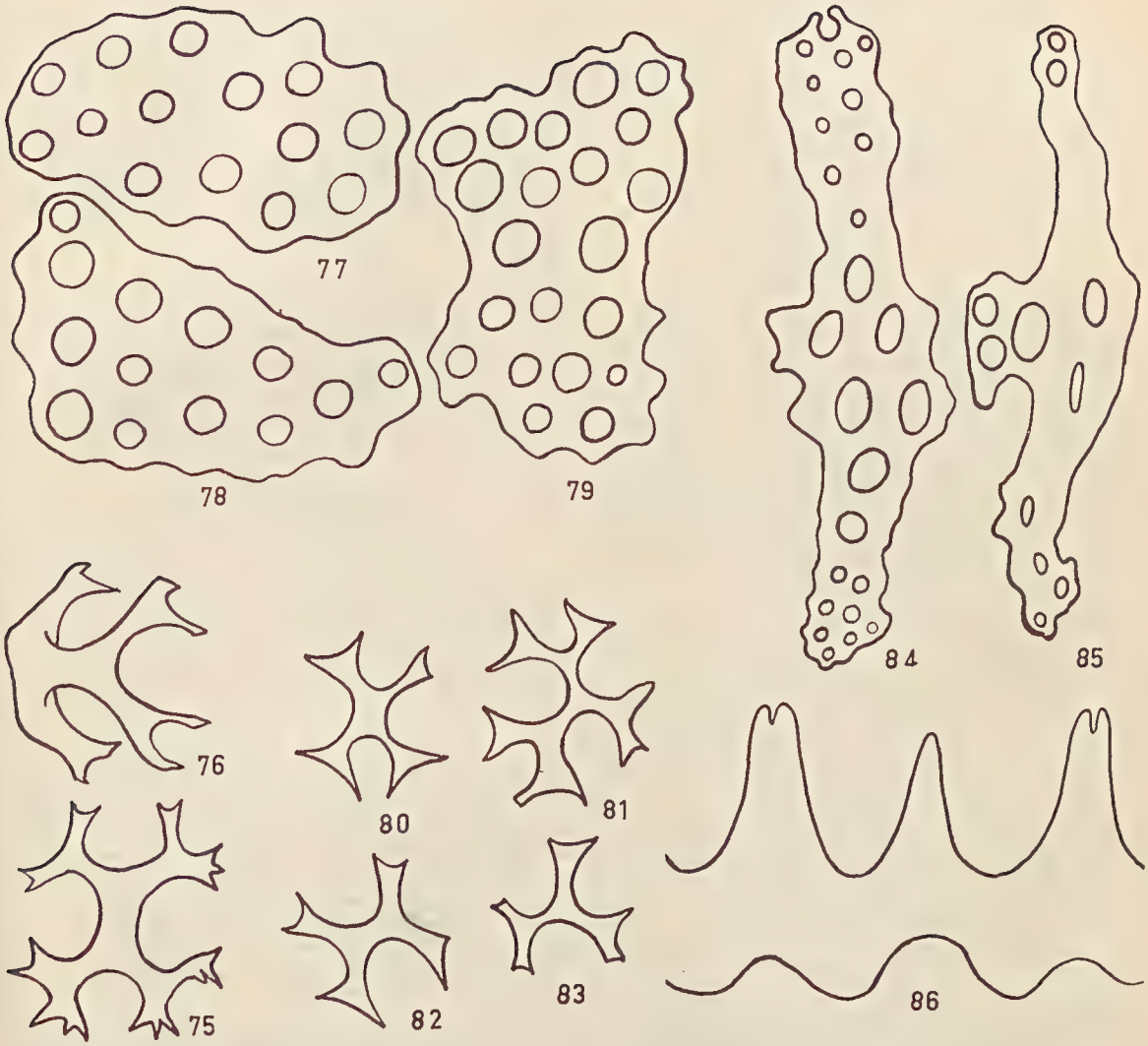
Calcareous bodies or spicules are present in the skin of the body-wall, introvert, tentacles and pedicels, but are absent from the peristome.

In the superficial skin of the body-wall the spicules are in the form of numerous small crosses measuring 48-81μ long and 45-66μ wide. The arms of the crosses are generally curved towards the surface and forked twice, the ends of the forks being provided with short spines (text-figs 75-76). In a deeper layer of the dorsal epidermis are very large thick scales, made up of reticulate strata and measuring up to 1.5 mm. long and 1.2 mm. wide. Around the posterior end of the body the scales are imbricated and visible externally.

The skin of the sole is supported by numerous perforated plates, which often overlap. They measure up to 238μ long and 140μ wide. They generally have about 12 holes but up to 16 may be present (text-figs. 77-79). In a more superficial layer there are branched particles with the ends of the branches forked (text-figs. 80-83). Crosses similar to those of the dorsal surface are also present but less numerous.

The skin of the introvert is supported by crosses, small perforated plates and small scales.

The pedicels and tentacles have spicules in the form of curved perforated bars (text-figs. 84-85).




*Psolidium ravum* sp. n.

FIGS. 75-76.—Crosses from outer layer of body-wall. FIGS. 77-79.—Perforated plates from sole. FIGS. 80-83.—Branched particles from sole. FIGS. 84-85.—Perforated bars from tentacles. FIG. 86.—Three ossicles from the calcareous ring.

In the pedicels a few crosses are also present. The end plate is large in the ventral pedicels but somewhat reduced in those of the dorsal surface.

The calcareous ring consists of five radial and five interradial ossicles of similar form. The ossicles are pointed in front and excavated on the posterior margin (text-fig. 86).

The intestine exhibits the usual contortion, the third loop being attached to the mesentery in the right ventral interradius. The respiratory trees are large and strongly branched.

The retractor muscles of the dorsal side are long and attached posteriorly near the middle of the body; those of the ventral side are much shorter and attached further forward.

The gonad is situated dorsally near the middle of the body. In the female it consists of numerous pale-yellow tubules, which occupy most of the body cavity. Mature ova measure about 0.25 mm. in diameter.

*Locality*: The Derwent Estuary; Blackman's Bay, 27th January. 1956; one specimen collected under a stone at low tide. Ralph's Bay, 28th August, 1959; one specimen dredged at a depth of about seven fathoms.

Order: ASPIDOCHIROTA.

Family: STICHOPODIDAE.

Genus: **STICHOPUS** J. F. Brandt, 1835.

*Stichopus mollis* (Hutton).

(Pl. II, fig. 8 and text-figs. 87-105.)

*Holothuria mollis* Hutton, 1872.
*Stichopus mollis* Dendy. 1897.
" " Erwe, 1913.
" " Joshua, 1914.
" " Mortensen. 1925.
" " Clark, 1938.
" " Clark, 1946.
*Stichopus simulans* Dendy & Hindle, 1907.
*Stichopus simultans* Erwe, 1913.

(For further synonymy *vide* Mortensen, 1925.)

This species was originally described from New Zealand and has since been recorded from Victoria, Western Australia and Tasmania.

Clark (1938) mentions having dredged a number of specimens of this large holothurian in 2-3 fathoms on the west side of the estuary at Hobart on 15th November, 1929. His specimens measured 160-250 mm. long and varied in colour from grey to brown. He remarks that they were " apparently the largest yet recorded ".

Specimens in the present collection vary in length from 20-280 mm. and in width from 5-35 mm. Most of them are dark purple-brown in colour, one is orange-brown and another, taken on a sandy bottom, is yellowish above and brown below, with the papillae, pedicels and tentacles brown. Small specimens found near the shore at low tide level are usually of a uniform dark-brown colour.

The body is almost cylindrical and on the dorsal side at the anterior end is produced into an irregular brim overhanging the pale-coloured peristomial region and tentacles. Around the margin of the peristome is a set of twenty peltate tentacles, which are partly retractible. When the holothurian is contracted the brim closes over the oral region concealing the mouth and the retracted tentacles.

The body-wall is tough and thick. The dorsal surface is furnished with large and small conical papillae but is devoid of pedicels. The ventral surface, which is slightly flattened, has numerous pedicels, which are situated on the three ventral radii and the two ventral interradii.

Calcareous spicules occur in large numbers in the body-wall. the stems of the tentacles, the peristome, pedicels, introvert, walls of the radial vessels, wall of the mid-gut and cloaca, but not in the wall of the intestine.

Spicules from the skin in the mid-body region have the form of tables with a short spire or tower. The basal plate is more or less circular, about 60$\mu$ in diameter and perforated with four large and four small holes. The tower is composed of four columns linked together by cross bars at the top and near the middle. In some spicules the tower is wide and short, its height being equal to about half the diameter of the basal plate (text-figs. 87-88). In other spicules the tower is narrower and its height equal to about three-quarters of the diameter of the basal plate (text-figs. 89-90). This second type of tower is similar to that observed by Mortensen (1925) in a young *Stichopus* from Paterson Inlet, Stewart Island. As he had not seen this type of spicule in adult specimens of *Stichopus mollis*, he thought the young specimen might perhaps belong to a different species. Since the tall as well as the short towered spicules occur in adult specimens of *Stichopus mollis* in Tasmania, there is little doubt that the juvenile form examined by Mortensen was a young specimen of that species. In both spicules the tower is provided with a crown of small spines. Stages in the development of a spicule from a primary cross are shown in text-figs. 91-94.

In the introvert the spicules are not as numerous or as large as in the body wall of the mid-body region. They have a large basal plate, about 42$\mu$ in diameter, perforated with four holes and provided with a tower of four columns. The columns are joined together by cross bars at the top but not near the middle. The height of the tower is about half the diameter of the basal plate. The crown has four short spines (text-figs. 95-96).

The spicules supporting the walls of the pedicels are similar to those of the body-wall. A large cribriform plate is present in the end of the pedicel.

The stems of the tentacles are provided with spicules in the form of curved rods covered with small projections (text-figs. 97-98). Similar but smaller rods occur in the peristome, walls of the radial vessels, wall of the mid-gut and wall of the cloaca (text-figs. 99-101). Around the anal aperture the skin often has rosettes (text-figs. 102-104) in addition to the ordinary spicules of the body-wall.

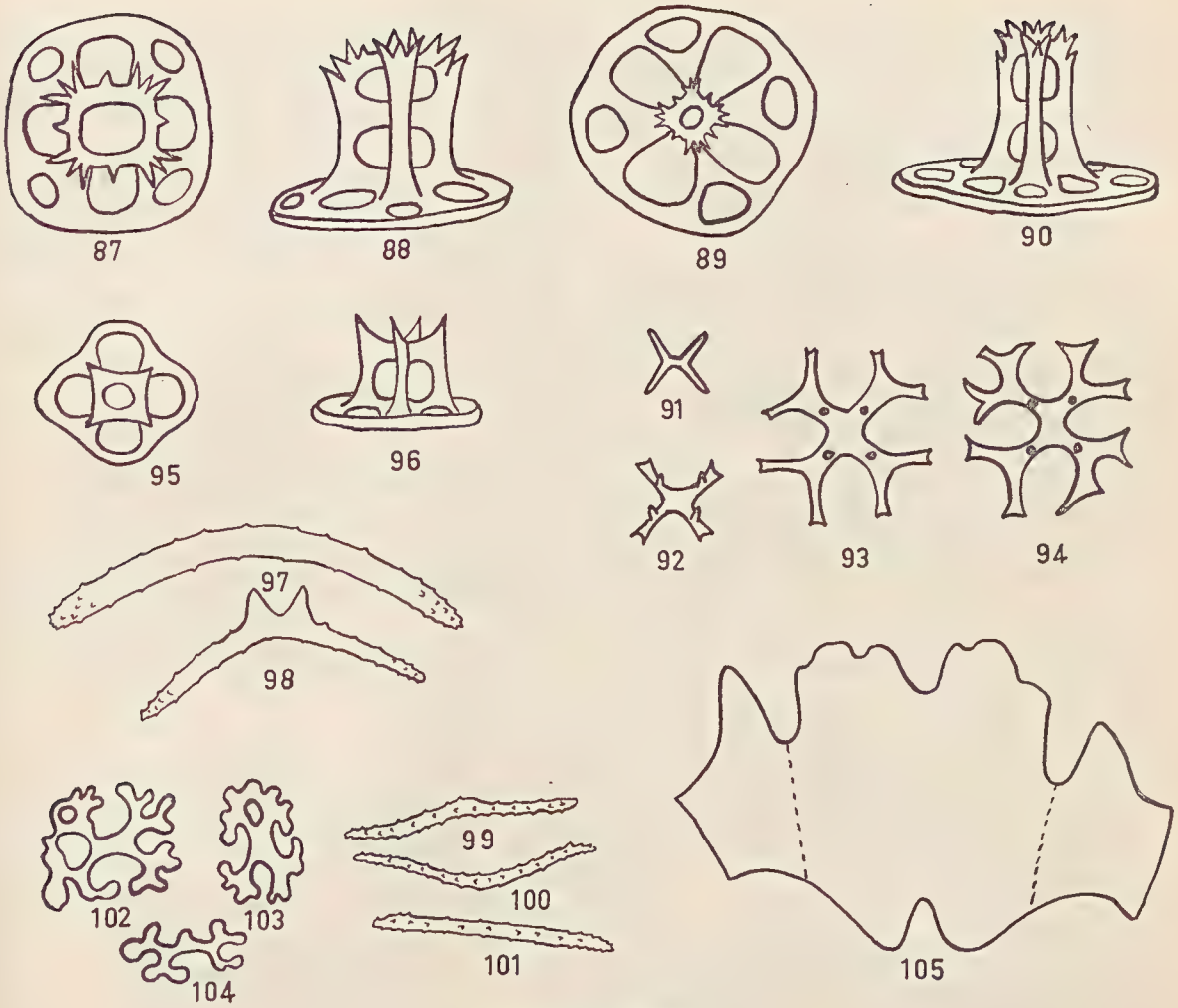
The calcareous ring has five radial and five interradial ossicles. The radials are wide and deeply notched in front and behind. The interradials are narrow, pointed in front and concave on the posterior margin (text-fig. 105).

The respiratory trees are large and well branched. Cuvierian organs are not prescent.

The vascular ring is connected dorsally with a single stone canal, which lies in the dorsal mesentery and ends in an ovoid madreporite. A single large Polian vesicle opens into the ventral side of the ring. Each tentacle is provided with a large ampulla.

The gonad is situated dorsally in the anterior quarter. In a female specimen, measuring 120 mm. long, the gonad consists of about eight primary tubules on each side of the dorsal mesentery. They open into the expanded end of the common genital duct. Distally they form numerous branches extending into the body cavity. Mature ova are small, measuring about 135$\mu$ in diameter.

*Localities*: Frederick Henry Bay: one collected on beach at Carlton, 3rd April, 1948; one dredged by D. Kurth at Lewisham, 8th November, 1952; one found under a stone on the shore at low tide at Lewisham, 14th November, 1952; and one collected on Seven Mile Beach, 25th April, 1960. Derwent Estuary: one found under a stone at low tide, Blackman's Bay, 1st November, 1952; fourteen dredged in 6-7 fathoms in Ralphs Bay by J. L. Hickman, 14th April, 1955; two on 29th August, 1955; and one on 28th August, 1959. D'Entrecasteaux Channel; three collected at low tide at Oyster Cove by E. R. Guiler, 18th November, 1952.




*Stichopus mollis* (Hutton).

FIGS. 87-88.—Table with wide tower viewed from above and side respectively. FIGS. 89-90.—Table with narrow tower viewed from above and side respectively. FIGS. 91-94.—Stages in the development of a table from a primary cross. FIGS. 95-96.—Table from introvert viewed from above and side respectively. FIGS. 97-98.—Rods from tentacles. FIGS. 99-101.—Rods from wall of mid-gut. FIGS. 102-104.—Rosettes from skin near anal aperture. FIG. 105.—Three ossicles from the calcareous ring.

Order: MOLPADONIA.

Family: MOLPADIIDAE.

Genus: **PARACAUDINA** Heding, 1932.

*Paracaudina australis* (Semper).

(Pl. II, fig. 9 and text-figs. 106-130.)

*Molpadia australis* Semper, 1868.
*Caudina chilensis* Clark, 1908.
" " Joshua, 1914.
" " Joshua & Creed, 1915.
*Caudina australis* Mortensen, 1925.
*Pseudocaudina australis* Heding, 1931.
*Paracaudina australis* Heding, 1932.
" " Heding, 1933.
" " Clark, 1935.
" " Clark, 1946.

After stormy weather this large holothurian is sometimes washed up on Seven Mile Beach in considerable numbers. Its normal colour is brown, but many specimens appear partly white due to the superficial skin having been eroded by the action of the sand and waves.

The body is fusiform in shape and may reach a length of 220 mm. and a width of 50 mm. It tapers posteriorly but there is little evidence of a tail. This is not due to the specimens being damaged or strongly contracted. The presence of the anal papillae indicates that the posterior end has not been lost. Moreover, living specimens placed in sea water extend but show no signs of a distinct tail.

The mouth is surrounded by fifteen short tentacles, each of which ends in four short lobes. Internally each tentacle possesses a large ampulla. The anal aperture is encircled by five groups of papillae, each group being radial in position. Pedicels are absent.

Calcareous particles or spicules are not present in the tentacles and peristome but occur in large numbers in the skin of the introvert, body-wall and anal papillae.

In the body-wall the most characteristic spicules have the form of rounded perforated plates about 63$\mu$ in diameter. The plates usually have six to eight holes of unequal size. Short conical knobs also frequently occur on both inner and outer surfaces of the plates. In addition to the rounded plates there are others which may have a few projections around the margin. Small plates with only three or four perforations and larger plates with up to eleven holes are present in smaller numbers (text-figs. 106-113).

In the skin of the introvert the spicules are similar to those of the body wall but smaller and with fewer holes. The rounded forms are less numerous than those with marginal projections and not many of the spicules are furnished with knobs (text-figs. 114-120).

The skin of the posterior end of the body and of the anal papillae is provided with numerous

*Paracaudina australis* (Semper).

FIGS. 106-113.—Perforated plates from body-wall. FIGS. 114-120.—Plates from introvert. FIGS. 121-128.—Small plates from posterior end of body. FIG. 129.—Four irregular particles from posterior end of body. FIG. 130.—Three ossicles from the calcareous ring.

small spicules having marginal projections, two or three holes and one or two knobs (text-figs. 121-128). In addition large numbers of small irregular particles are present (text-fig. 129).

The calcareous ring consists of five radial and five interradial ossicles. The radials are long and narrow with a deep cleft posteriorly (text-fig. 130). The interradials, which are intimately fused with the radials, are slightly less than half their length. They have almost parallel sides and an excavated posterior margin.

The respiratory trees are extensive and have numerous branches. Cuvierian organs are not present.

The radial muscles bands are wide and double. The retractor muscles are short having their posterior ends attached only a short distance behind the ring vessel.

A single madreporite is present and is situated in the dorsal mesentery. It comunicates with the dorsal side of the ring vessel. A large Polian vesicle opens into the ventral side of the vessel.

The gonad consists of a large number of branched tubules disposed in two tufts, which arise one on each side of the dorsal mesentery in the anterior quarter of the body cavity.

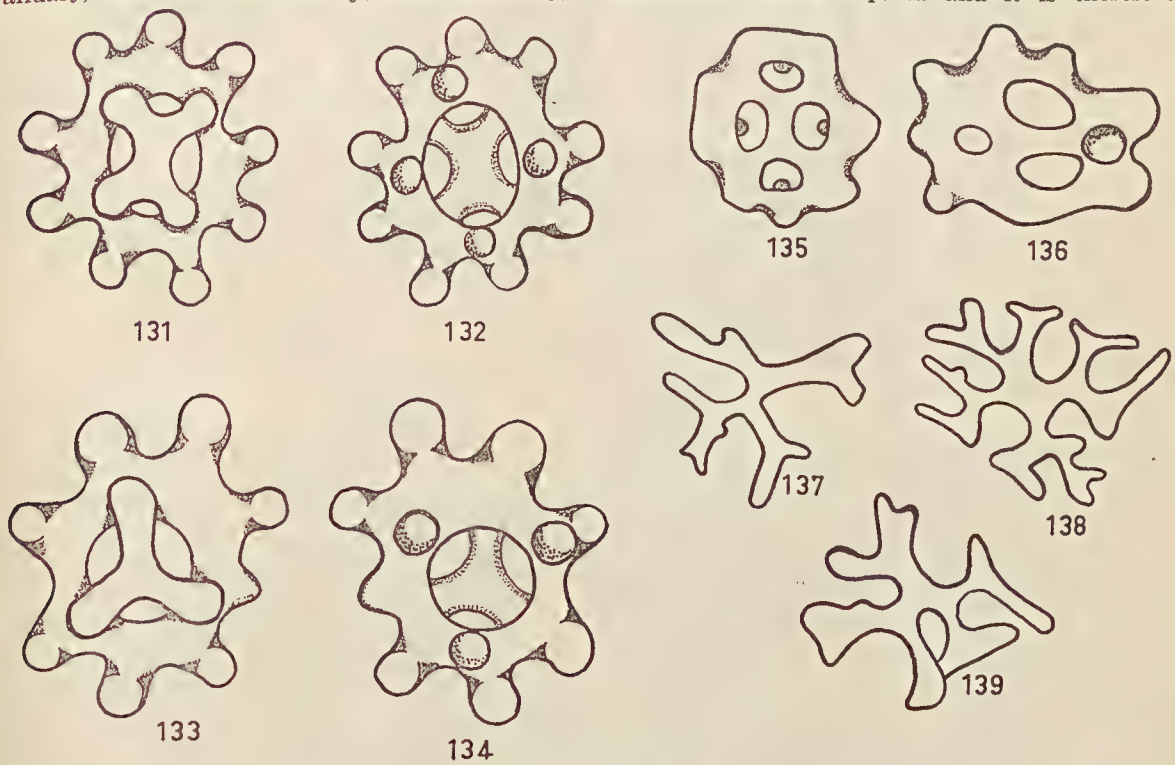
*Localities*: Bridport, one washed up on beach, January, 1928. Derwent Estuary: Blackman's Bay, two, 18th October, 1951. Kingston Beach, two, 13th October, 1952. Frederick Henry Bay: Seven Mile Beach, thirteen collected by E. R. Guiler and A. G. Lyne, 14th October, 1952; eleven by J. L. Hickman, 13th August, 1956; twenty-eight by J. L. Hickman and the writer, 20th October, 1956; fifty-four by J. L. Hickman, 6th September, 1957. In all cases the specimens were found washed up on the shore usually after rough weather.

## *Paracaudina luticola* sp. n.

(Text-figs. 131-139.)

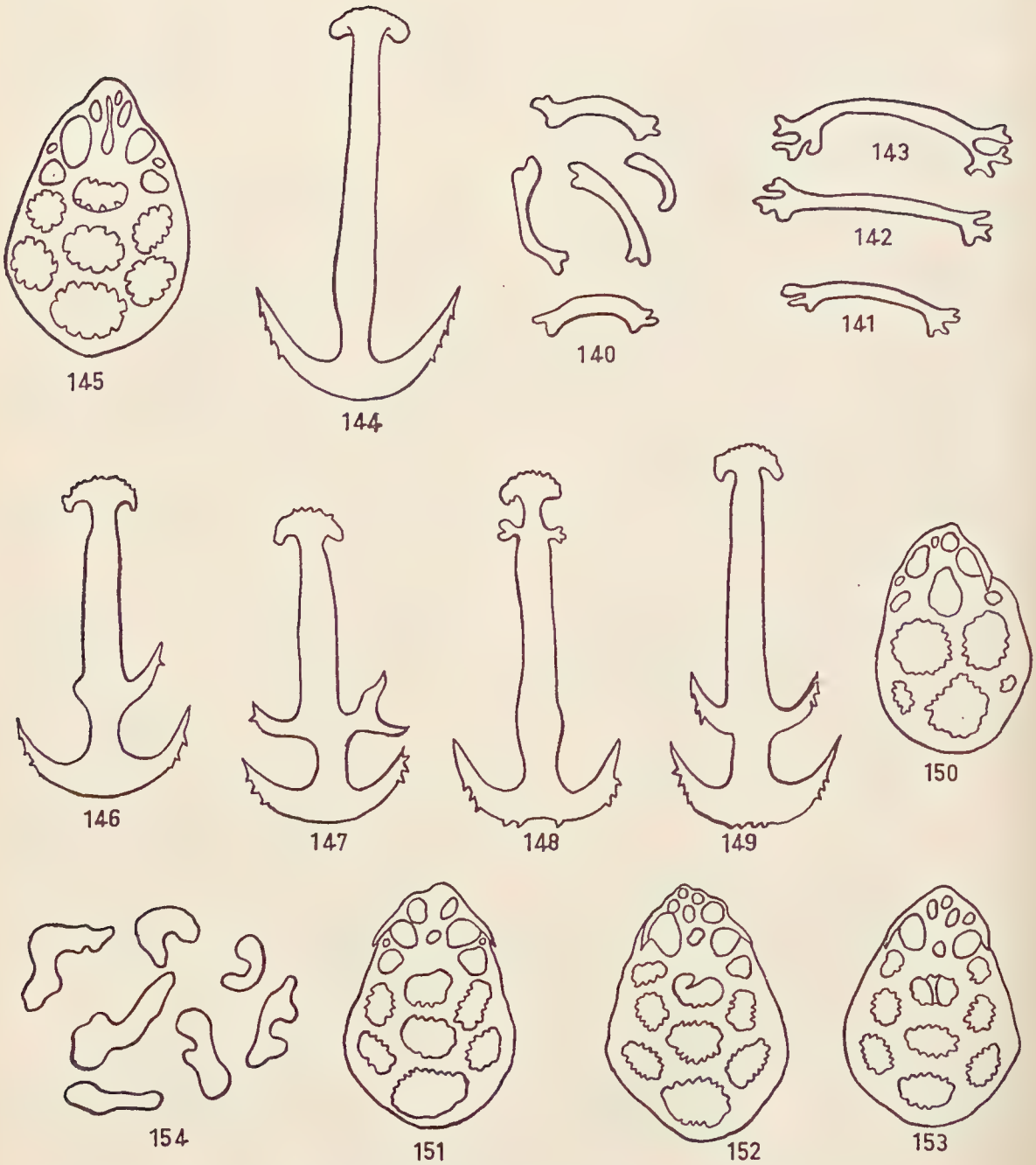
During dredging in Ralphs Bay, 30th June, 1959, seven caudal appendages were obtained. The form of the calcareous particles in the skin of the appendages indicates that they belong to holothurians of the genus *Paracaudina* and apparently to a new species. The animals seem to be buried in the sandy mud at the bottom of the bay with only their caudal extremities reaching the surface of the mud and thus being cut off by the blade of the dredge. Mortensen (1925) obtained only caudal appendages of *Paracaudina coriacea* (Hutton), when dredging in Colville Channel and Tiri-Tiri, New Zealand, in 1914.

Unfortunately further dredging in Ralphs Bay has failed so far to yield a complete specimen of *Paracaudina luticola* sp. n. and it is therefore




*Paracaudina luticola* sp. n.

FIGS. 131-132.—Crossed cups showing outer and inner surfaces respectively. FIGS. 133-134.—Crossed cups with three arms to the cross showing outer and inner surfaces respectively. FIGS. 135-136.—Small perforated plates from integument. FIGS. 137-139.—Spicules from anal papillae.




*Leptosynapta dolabrifera* (Stimpson).

FIG. 140.—Rods from main stem of tentacle. FIGS. 141-143.—Rods from digits. FIGS. 144-145.—Anchor and anchor-plate from body-wall. FIGS. 146-153.—Abnormal anchors and anchor-plates. FIG. 154.—Miliary granules from integument above radial muscle bands.

possible to describe only the caudal appendages obtained. They are pale-yellow almost white in colour and measure 16-27 mm. long and 4 mm. wide. Owing to marked contraction the surface is strongly corrugated. The body-wall is thick and tough. The skin is furnished with numerous calcareous particles. At the posterior end the anal aperture is surrounded by 22-32 papillae, which are narrow and finger-like.

The calcareous particles consist very largely of crossed cups (text-figs. 131-132). The margin of the cup is produced into 7-10 rounded knob-like processes. On the outer surface of the particle is an X-shaped cross, which partly covers a large central hole, which is the only perforation. On the inner surface of the particle and opposite the angles of the cross are four rounded knobs. Most of the spicules measure 45-51$\mu$ in diameter. In some cases only three arms of the cross on the outer surface and three knobs on the inner surface are developed (text-figs. 133-134).

Some spicules have the form of small plates with three or four perforations and without well rounded marginal knobs (text-figs. 135-136).

The anal papillae are supported by branched spicules of irregular form (text-figs. 137-139).

*Locality*: Derwent Estuary: Ralphs Bay. Seven caudal appendages dredged in about 7 fathoms by J. L. Hickman, 30th June, 1959.

*Affinities*: The typical crossed-cup spicules of *Paracaudina luticola* sp. n. differ from those of *P. chilensis* (Müller) and its varieties *coriacea, obesacauda* and *ransonnetii* in the basal plate lacking marginal perforations, and also in the large central hole of the plate not being barred on the inner side by a square plate with a large perforation in its centre. The presence of crossed-cup spicules in large numbers clearly distinguishes the new species from *P. australis* (Semper) and *P. tetrapora* (Clark), in both of which crossed-cups are lacking or reduced.

Order: APODA.

Family: SYNAPTIDAE.

Genus: **LEPTOSYNAPTA** Verrill, 1867.

*Leptosynapta dolabrifera* (Stimpson).

(Pl. II, fig. 10 and text-figs. 140-154.)

*Synapta dolabrifera* Stimpson, 1855.
*Leptosynapta dolabrifera* Clark, 1908.
" " Clark, 1924.
" " Heding, 1928.
*Leptosynapta variopatina* Heding, 1928.
*Leptosynapta jacksonia* Heding, 1928.
*Leptosynapta dolabrifera* Clerk, 1938.
*Leptosynapta dolabrifera* Clark, 1946.

This common synaptid was first recorded from Tasmania by H. L. Clark (1938), who examined and identified nine specimens dredged by T. T. Flynn in Ralphs Bay and the Derwent River.

The present collection contains 45 specimens. The largest, when alive and extended, measured 220 mm. in length. The living holothurian has a translucent appearance and is usually pale-yellow or white. Some examples are almost colourless. Specimens which have been narcotised with menthol and preserved in alcohol measure up to about 150 mm. in length and 6 mm. in width.

The mouth is surrounded by twelve tentacles, each of which has six or eight pairs of finger-like lobes. The inner surface of the main stem of each tentacle is provided with sensory papillae, which vary in number from about six in specimens 35 mm. long to about twenty-seven in the largest specimens. The number and arrangement of the papillae differ on the several tentacles of the one animal.

Calcareous particles or spicules are present in the tentacles and the body-wall. In the tentacles the spicules have the form of slightly curved rods with several knobs at each end (text-figs. 140-143). They measure 36-81$\mu$ in length. Those in the main stem of the tentacle are stouter, more curved and not so strongly knobbed as compared with those in the digits.

In the body-wall the spicules have the characteristic form of anchors and anchor-plates. The anchors vary in length from 178-288$\mu$ and in width from 96-164$\mu$. The arms have four to six serrations (text-fig. 144). The anchor-plates have the form shown in text-fig. 145. They measure 137-192$\mu$ in length and 103-137$\mu$ in width.

A specimen collected at Beauty Point in the Tamar Estuary exhibited strongly abnormal anchors and plates. Some of the abnormalities are shown in text-figs. 146-153. Many of the anchors showed a tendency to form a second pair of arms or projections on the main stem.

In the integument overlying the radial muscle bands there are numerous miliary granules, 27-42$\mu$ in length (text-fig. 154).

The calcareous ring consists of five radial and seven interradial ossicles, there being two interradial ossicles situated in both the right and the left dorsal interradius. Each radial ossicle is perforated by a foramen.

Two to four Polian vesicles are present. The madreporic canal is single, unbranched and attached to the dorsal mesentery. Ciliated funnels are situated in the left dorsal interradius. They are numerous and are distributed almost the full length of the body.

The sexes are separate and in both the male and the female the gonads ar long, tubular and branched. The genital aperture is situated on a small papilla in the mid-dorsal line close behind the tentacles.

*Localities*: Eaglehawk Neck, May, 1942, one specimen. Beauty Point, River Tamar, February ,1950, twenty-six. Margate, 22nd October, 1952. four. Oyster Cove, 18th November, 1952, one. Wyn, ırd, 24th August, 1954, one immature example. At all the above-mentioned localities the specimens were found more or less embedded in sandy mud under stones near low tide mark. Ralphs Bay, 14th April, 1955, one specimen; 18th August, 1955, two; 19th August, 1955, two; and 30th June, 1959, three. All were obtained by dredging in about seven fathoms. Seven Mile Beach, 29th December, 1955, four collected from kelp holdfasts washed up on the beach.

Family: CHIRIDOTIDAE.

Genus: **CHIRIDOTA** Eschscholtz, 1829.

*Chiridota gigas* Dendy & Hindle.
(Pl. II, fig. 11 and text-figs. 155-166.)

*Chiridota gigas* Dendy & Hindle, 1907.
" " Joshua, 1914.
" " Mortensen, 1925.
" " Clark, 1938.
" " Clark, 1946.

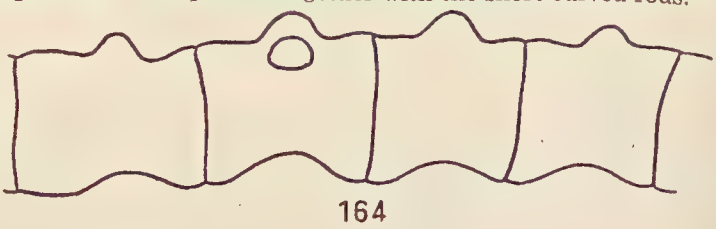
The generic name *Chiridota* is spelt *Chirodota* by Dendy & Hindle in their description of the original specimen, which came from the Chatham Islands near New Zealand. The recorded occurrence of the species in Tasmanian waters is based on three small specimens collected at Wynyard by T. T. Flynn in 1927 and identified by H. L. Clark (1938). The largest of the specimens measured only 100 mm. in length.

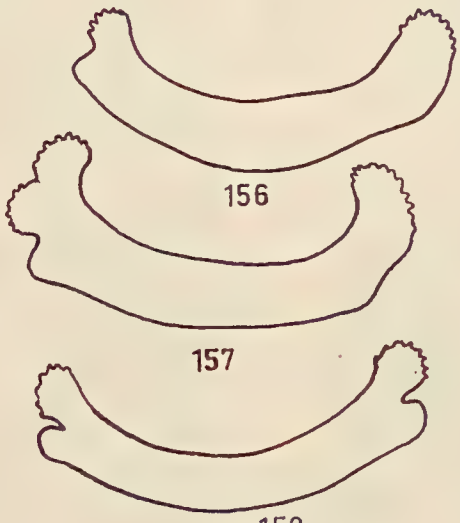
In the present collection there are 31 specimens of the holothurian. A well extended example measures 248 mm. long and 15 mm. wide. Preserved adult specimens usually measure about 120-160 mm. in length. In life the body is yellowish-pink anteriorly but the colour merges into dark-red posteriorly. The tubercles or papillae distributed over the surface are white and give the body a speckled appearance. In preserved specimens the body colour is generally bleached.

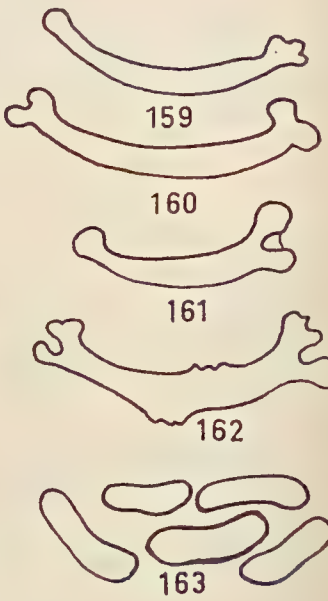
Twelve tentacles are present, the ventral pair being slightly smaller than the others. Each tentacle has seven pairs of digits, which increase in length distally.

The calcareous particles in the tentacles and body-wall agree closely with those found in the specimen examined by Dendy & Hindle. Six-rayed wheels (text-fig. 155) measuring 78-135$\mu$ in diameter are numerous in the white papillae of the body surface. In most cases the number of wheels in a single papilla is over 100. The wheels are superimposed on one another forming a heaped mass. Intermingled with the six-rayed wheels are some which have only four rays and measure about 60$\mu$ in diameter.

Short curved rods (text-figs. 156-158) occur in five radial bands outside the radial muscles. The rods measure 72-129$\mu$ in length and 15-24$\mu$ in width. In some cases the ends are slightly bifurcate and furnished with short spines or tubercles. Short thick miliary granules up to 39$\mu$ long and 9$\mu$ wide are present together with the short curved rods.



*Chiridota gigas* Dendy & Hindle.

FIG. 155.—Wheel from a papilla of the body-wall. FIGS. 156-158.—Curved rods from integument above radial muscle bands. FIGS. 159-162.—Curved rods from main stem of a tentacle. FIG. 164.—Four ossicles from the calcareous ring. FIGS. 165-166.—Ciliate funnels.

The digits of the tentacles are supported by numerous slender curved rods arranged in two rows, one on each side of the digit. The rods measure 57-78$\mu$ in length and usually have knobbed ends (text-figs. 159-162). The main stem of each tentacle has numerous short thick rods with rounded ends. Near the base of the tentacle they are densely arranged and more or less straight. They measure 27-51$\mu$ in length (text-fig. 163).

The calcareous ring consists of five radial and seven interradial ossicles. Each radial is perforated by a well-developed foramen, a feature not mentioned by Dendy & Hindle in the case of their specimen. Moreover, in the Tasmanian specimens each of the twelve ossicles forming the ring has a distinct projection from the middle of the anterior margin (text-fig. 164).

In reference to the radial muscle bands Dendy & Hindle (1907) state that in their specimen "The two ventral muscle-bands are much closer together than the other three bands". There seems to be some error in the statement since in the organization of the holothurian there are three ventral bands. In the Tasmanian specimens the five radial bands are evenly spaced. However, the three ventral bands are somewhat stouter than the two dorsal ones.

The ring vessel is furnished with a large number of Polian vesicles, all of which are given off from the ventral half of the ring. In the largest specimen 25 Polian vesicles are present. In two smaller examples there are 19 and 21 vesicles respectively. The madreporic canal is single, coiled and situated in the dorsal mesentery in front of the gonads.

Neither Dendy & Hindle (1907) nor Joshua (1914) refer to the presence of ciliated funnels in the specimens they examined. Mortensen (1925), however, mentioned ciliated funnels as occurring in the left dorsolateral interradius of a specimen from Dusky Sound, New Zealand. Ciliated funnels occur in a similar situation in Tasmanian specimens. The funnels are numerous forming a band which extends almost the full length of the interradius. They have the form shown in text-figs. 165 and 166.

The gonads are in the form of branched tubular caeca. They are arranged in two groups, one on each side of the dorsal mesentery in the anterior quarter of the body . The caeca unite near the genital aperture, which opens in a mid-dorsal position close behind the tentacles. In a large female there are six caeca on each side of the mesentery. In life the gonads of the female are bright orange, those of the male pale yellow.

*Localities*: Coal Point, Bruny Island, January, 1937, one specimen. Pirates Bay, Eaglehawk Neck, 31st October, 1955, two; 13th February, 1960, six; 12th-15th March, 1960, twenty-two . All specimens were found more or less embedded in sand and shell-grit under stones at low tide mark.

Genus: **TROCHODOTA** Ludwig, 1892.

*Trochodota allani* (Joshua).

(Pl. II, fig. 12 and text-figs. 167-176.)

*Taeniogyrus allani* Joshua, 1912.
*Trochodota allani* Joshua, 1914.
" " Clark, 1938.
" " Clark, 1946.

This little holothurian was first recorded from Victoria, where it occurs abundantly in the mud of Port Phillip Bay. The record of its occurrence in Tasmania is based on a single small specimen from the estuary of the Derwent. The specimen was dredged near Hobart, 15th November, 1929, and identified by Clark (1938).

The present collection contains twenty-three examples, the largest being 82 mm. long and 5 mm. in diameter. In life the holothurian is usually dark-purple in colour but becomes grey when preserved in alcohol.

The mouth is surrounded by ten tentacles, the three ventral ones being slightly smaller than the others. Each tentacle is provided with four or five pairs of digits.

Calcareous particles are of three kinds, namely wheels, sigmoid bodies and curved rods with knob-like projections. The wheels and sigmoid bodies occur chiefly in the skin of the trunk, and are scattered in both the radii and interradii. The wheels (text-fig. 167) have the form of rounded hexagons, the largest being about 216$\mu$ in diameter. Each is provided with six spokes. The sigmoid bodies (text-figs. 168-169) measure 132-150$\mu$ in length. The curved rods with knob-like projections (text-figs. 170-173) occur in the tentacles. They measure 72-81$\mu$ in length.

The calcareous ring consists of five radial and five interradial ossicles. They have the form shown in text-fig. 174. The radials are not perforated by a foramen.

A single Polian vesicle is given off from the ventral side of the ring vessel. Joshua (1912) states that a stone canal is "apparently absent". This however is not the case in the Tasmanian specimens. The canal, though small, is definitely present, being situated in the dorsal mesentery immediately in front of the gonad. It measures about 490$\mu$ in length. The madreporite is circular and 112$\mu$ in diameter.

Ciliate funnels occur in the left laterodorsal, the dorsal and the right ventral interradius . They have the form shown in text-figs. 175-176 and measure 180-285$\mu$ in height.

In both sexes the gonad consists of two long unbranched tubular caeca, one on each side of the dorsal mesentery. The two cacea unite in a common gonoduct slightly behind the vascular ring. The gonoduct passes forward in the dorsal mesentery and opens at the genital aperture, which is situated in a mid-dorsal position at the base of the tentacles. In a female specimen well advanced ova measured 164$\mu$ in diameter.

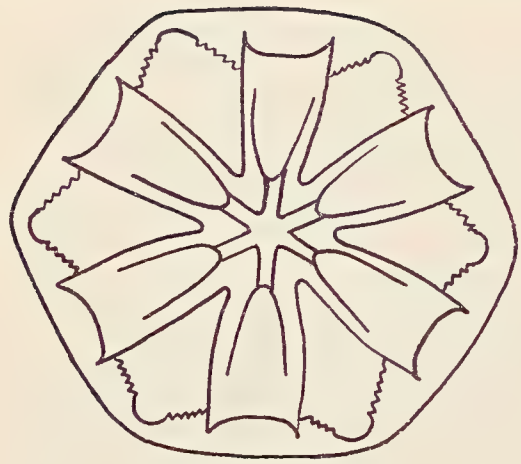
*Locality*: Ralph's Bay. April, 1955, seventeen, specimens; August, 1955; nineteen; all dredged at about 7 fathoms on a muddy bottom.

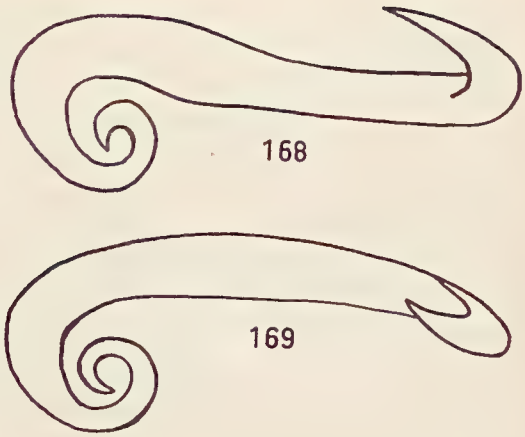
*Trochodota roebucki* Joshua.

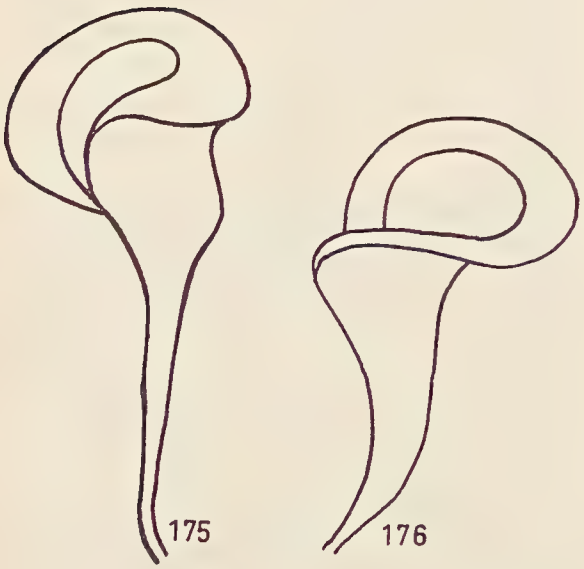
(Pl. II, fig. 13 and text-figs. 177-186.)

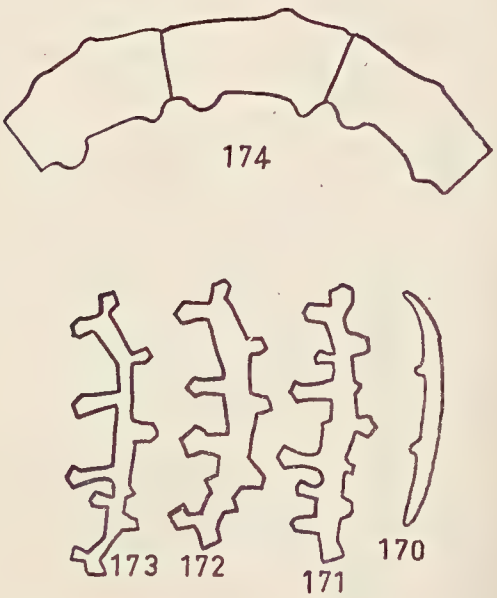
*Trochodota roebucki* Joshua, 1914.
" " Clark, 1938.
" " Clark, 1946.

This small chiridotid has been recorded from Torquay in Victoria (Joshua, 1914) and from Geraldton and Rottnest Island in Western Aus-




*Trochodota allani* (Joshua).

FIG. 167.—A wheel from the body-wall. FIGS. 168-169.—Sigmoid particles from body-wall. FIGS. 170-173.—Knobbed rods from tentacles. FIG. 174.—Three ossicles from the calcareous ring. FIGS. 175-176.—Ciliated funnels.

tralia (Clark, 1946), but hitherto has not been recorded from Tasmania.

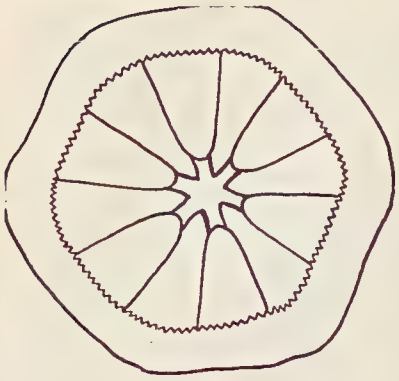
In the present collection there are ten specimens from the estuary of the Tamar. When alive the holothurian is almost colourless and translucent. When preserved in alcohol it becomes yellowish and opaque.

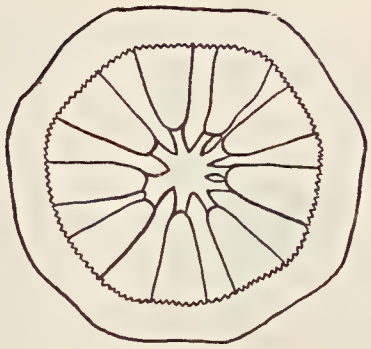
After being narcotised with menthol and preserved in spirit, the largest specimen measures only 35.0 mm. long and 2.00 mm. wide.

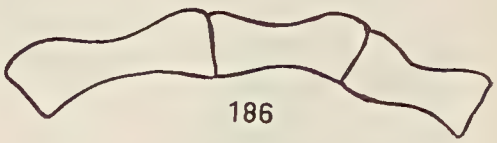
Ten tentacles are present, the ventral ones being smaller than the others. Each has two pairs of digits, the distal pair being longer than the proximal pair (text-fig. 177).

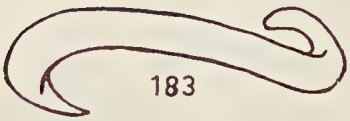
Calcareous particles are present in the tentacles and the body-wall. In the tentacles they have the form of slightly curved rods with projections at each end and along the sides (text-figs. 178-180). The rods measure about 90$\mu$ in length.

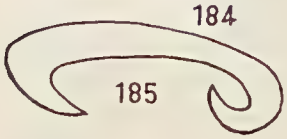
In the wall of the trunk the spicules have the form of wheels and sigmoid bodies. The wheels

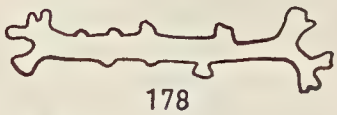


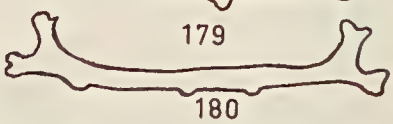










*Trochodota roebucki* Joshua.

FIG. 177.—A tentacle showing the four digits. FIGS. 178-180.—Knobbed rods from tentacles. FIGS. 181-182.—Wheels from body-wall. FIGS. 183-185.—Sigmoid particles from body-wall. FIG. 186.—Three ossicles from the calcareous ring.

occur interradially. They are scattered but are found in greater numbers near the radial muscles than in the middle of the interradial areas. They are somewhat hexagonal in outline and measure up to 105$\mu$ in diameter. Most of them have six rays, but some have seven or eight and a few ten. The inner margin of the rim of the wheel is uniformly toothed (text-figs. 181-182). Sigmoid bodies occur both radially and interradially. They measure up to 144$\mu$ in length and have the usual form (text-figs. 183-185). Those which occur radially are arranged in a row on each side of the radial muscle bands and have their long axes disposed transversely. Those which are interradial in position are scattered.

The calcareous ring has five radial and five interradial ossicles of similar form. They are somewhat constricted in the middle and expanded at each end (text-fig. 186). The radials are not perforated by a foramen.

A single Polian vesicle opens into the ventral side of the ring vessel and a single short madreporic canal is connected with the dorsal side of the vessel.

Ciliated funnels occur along the line of attachment of the mesentery in the mid-dorsal interradius.

As in the previous species the gonads have the form of a pair of long thin tubular caeca. They extend the full length of the body and unite anteriorly immediately behind the ring vessel. The gonoduct opens dorsally near the base of the tentacles.

*Locality*: River Tamar near Beauty Point. Ten specimens were collected during February, 1950. They were found embedded in sand and mud under stones near low water mark.

## ACKNOWLEDGMENTS.

My thanks are due to Dr. E. R. Guiler, Dr. D. E. Kurth, Messrs. A. M. Olsen, D. J. Cullen, D. Alexander and J. L. Hickman, all of whom have helped in collecting the holothurians described in the present paper.

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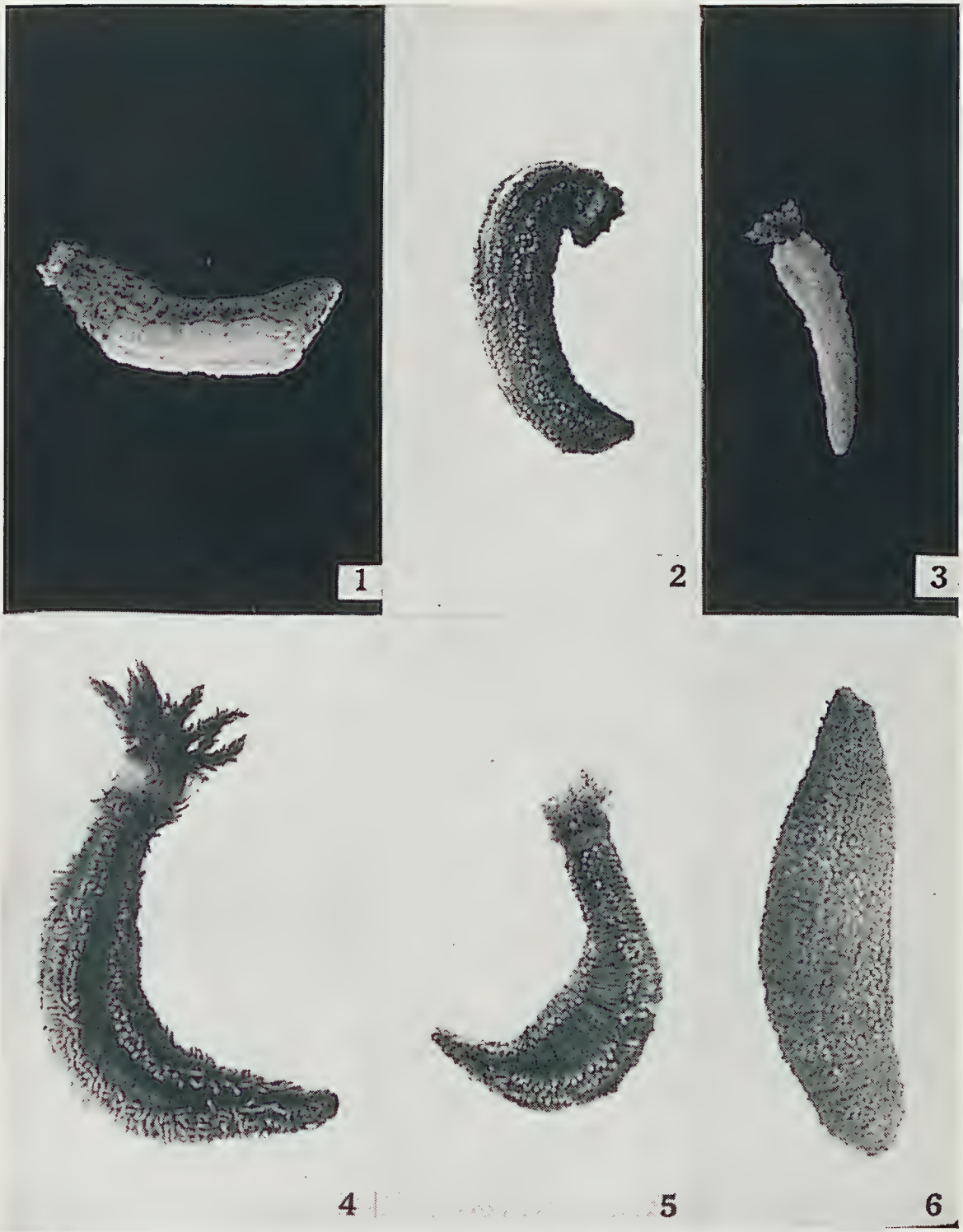



Plate I.

Fig. 1.—*Psolidiella adhaerens* sp. n. Fig. 2.—*Staurothyone inconspicua* (Bell). Fig. 3.—*Pentacta australis* (Ludwig). Fig. 4.—*Cucumella mutans* (Joshua). Fig. 5.—*Neoamphicyclus lividus* sp. n. Fig. 6.—*Lipotrapeza vestiens* (Joshua).

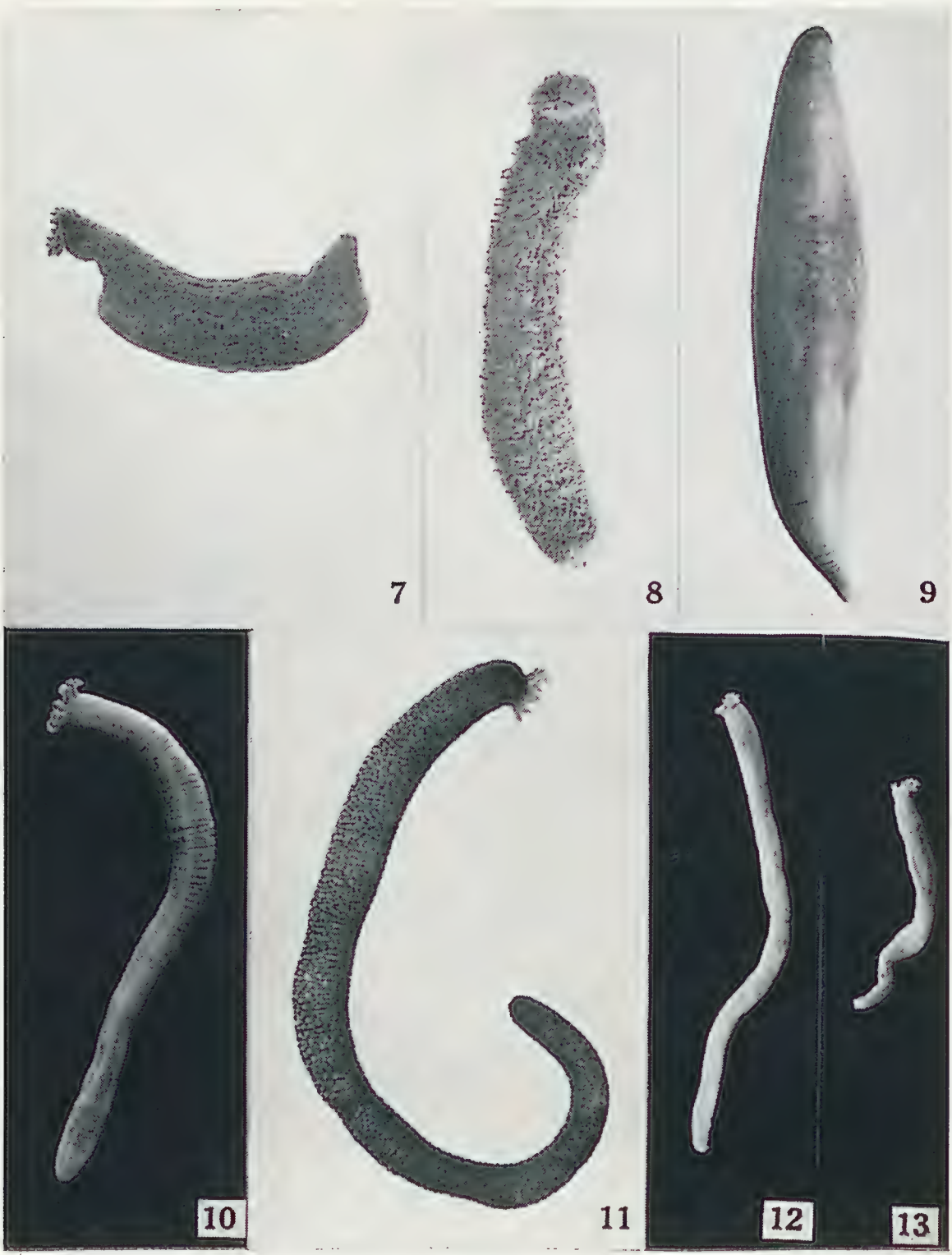



PLATE II.

FIG. 7.—*Psolidium ravum* sp. n. FIG. 8.—*Stichopus mollis* (Hutton). FIG. 9.—*Paracaudina australis* (Semper). FIG. 10.—*Leptosynapta dolabrifera* (Stimpson). FIG. 11.—*Chiridota gigas* Dendy & Hindle. FIG. 12.—*Trochodota allani* (Joshua). FIG. 13.—*Trochodota rocbucki* Joshua.

# NOTES ON SOME TASMANIAN AND AUSTRALIAN LEPIDOPTERA-RHOPALOCERA

By

L. E. Couchman.

(With four text figures and one plate)

## ABSTRACT

A ready method of separating the males of the two species of *Pelopidas, P. agna dingo* Evans and *P. lyelli lyelli* Rothschild, for long confused as one species under the name *mathias,* is described and figured. *Oreisplanus munionga larana* is described from north-west Tasmania, this is the first record of the genus in this State and of the species below a high altitude in the Australian Alps.

*Candalides simplexa* Tepper is shown to be the name for the collective species known as *hyacinthina* Semper, the latter is an invalid homonym, having formerly been used for another species of the same genus. Meyrick's name *cyanites* is revived for the West Australian race, and Scott's *cassythae* adopted to replace *hyacinthina* Semper. The species of *Everes* which has at various times been known in Australia as *E. parrhasius* or *E. argiades* is placed as a subspecies of *lacturnus* Godart and named *E. lacturnus australis. Zizula hylax* Fabricius is adopted as the species name of the butterfly for which *gaika* Trimen was formerly used, our species now becomes *Zizula hylax attenuata* Lucas.

The possible localities from which the original specimens of *Pseudalmenus chlorinda* Blanchard were obtained is discussed and historical and material evidence brought forward in support of my claim that Richmond, near Hobart, must be regarded as the source of Blanchard's specimens, and it is so designated as the type locality, and a neotype male and female selected.

The hitherto unknown female of *Oreixenica paludosa theddora* Couchman from the plateau area of Mt. Buffalo is described. The limits of the subspecies of *Heteronympha cordace* Geyer in Tasmania are more clearly defined as the result of further intensive collecting during the past seven years.

## HESPERIIDAE.

### PELOPIDAS AGNA DINGO Evans 1949 and PELOPIDAS LYELLI LYELLI (Rothschild) 1915.

When in 1951 (Trans. Roy. Soc. South Australia 74 (I) : 16-17) I discussed the confused history of these species formerly known in Australia as "*Parnara* (or *Baoris*) *mathias*" I had seen only a few specimens from Darwin and Kuranda. Evans' (1949) keys for their separation proved difficult to follow, and the earlier contradictions regarding the published figures have continued to confuse many correspondents. Having worked out a method for readily separating the males and communicated this to several friends I find this confirmed in T. Shirôzu's magnificently illustrated "Butterflies of Formosa" recently published in 1960, where similar figures are given for separating the Formosan subspecies of *P. agna* and *P. mathias.*

The males of our two Australian species may be separated as shown in the figures by checking the position of the male sex brand in relation to the origin of vein 2 and the position of the cell spots. A line drawn through the cell spots will clearly pass beyond the margin of vein 2 and cross vein 1b basad of the end of the sex brand in *agna dingo* male, while a similar line through the cell spots in *lyelli lyelli* will pass very close to or over the origin of vein 2 and clearly pass through the sex brand before crossing vein 1b.

In the females, except for the absence of the sex brand, a line similarly drawn will pass the origin of vein 2 as in the males, that is, the line in *agna dingo* will pass on the basal side of the spot in area 1b, whereas in *l. lyelli* female the extended line will clearly meet the spot in area 1b. I hope the publication of these figures will help others to distinguish between these two very similar species, so long confused.

The two species seem to overlap throughout their range in Australia, I have noted specimens of both from Darwin, Kuranda, and Cairns south to Mackay, but I believe one or both may range at least occasionally to Brisbane.

### OREISPLANUS MUNIONGA LARANA subsp.nov.

Nominotypical *munionga* Olliff 1890 (Proc. linn. Soc. N.S.W. (1889) (2) 4 (3) : 623-624) was described from "Moonbar (3-3550 feet), Mt. Kosciusko (5000 feet)" the former being fixed as the type locality by Waterhouse and Lyell (1914). It has subsequently been taken at several places in the Victorian Alps, especially on Mt. Hotham, but always above four thousand feet. Its occurrence at sea level, in fact almost on the shore-line in Tasmania was totally unexpected, since the species does not occur at low altitudes even in Victoria. When compared with typical *munionga* the differences in the Tasmanian race are easily recognised.

Male Upperside; Forewing, discal spots between veins 1 and 2 narrow, connecting with two spots each 1 mm. square in areas 2 and 3, three subapical spots and scattered submarginal scaling from costa to vein 4, a cell spot extending narrowly towards

*Heteronympha cordace* races in Tasmania

base and hindmargin almost sagittate and a few scattered scales on hindmargin half way from base, cream.

Hindwing cell band larger, 3 mm. by 1 mm., in area 5 clearly extended outwards towards termen.

Cilia of fore and hindwings broad, light cream chequered dark brown at veins 2 to 7.

Underside; forewing discal spots in areas 2 and 3 rectangular, of equal size, the spot in area I extending upwards towards spots in 2 and 3, the apical light cream area containing submarginal black streaks and marginal black spots which are distinctly smaller and narrower. Hindwing ground colour light cream, the markings narrower and submarginal spots smaller than in ssp. *munionga*.

Forewing length 11.5 mm., eight other males vary from 11 mm. (1 specimen); 11.5 (4 specimens); to 12 mm. (3 specimens).

Female. Upperside; forewing discal spots as in male, that in area 1 extending upwards towards those in area 2 and 3, cell spot clearly sagittate, and a light scaling in the post-discal areas, cream.

Hindwing central band 4 mm. by 2 mm., larger than in ssp. *munionga* female, extended towards termen in area 5 and with streaks along veins 2, 3 and 4 towards termen, orange. Cilia of fore and hindwings broad, as in male.

Underside cell spot extended along vein to base, otherwise as in the typical subspecies.

Forewing length 15 mm.

Holotype male labelled Marrawah, Tas. Sea-level. 26-Jan.-1961. L. E. Couchman. Allotype female labelled as holotype male. Types in my own collection.

Nine males and one female were taken in a dry paddock on the edge of a swampy rivulet containing a few clumps of *Carex*, which has been noted as the food-plant in Victoria. Obviously ssp. *larana* is extremely local since it has remained undiscovered till now, although occurring in a paddock in a long settled grazing district. No other specimens were seen outside the one narrow area in a single field close to the shore-line. though I should expect it to occur in similar spots bordering running water between Marrawah and Cape Grim. South of Marrawah the country quickly changes to heathland extending to the mouth of the Arthur River, so that its possible habitable area is extremely limited.

This addition to our Tasmanian lists should be placed between the genera *Anisynta* and *Hesperilla*.

## LYCAENIDAE.

### CANDALIDES SIMPLEXA SIMPLEXA (Tepper) 1882 n. Synon. and comb.

*Cupido simplexa* Tepper 1882 Trans. Roy. Soc. South Australia (1880-1) 4 : 30.2, f.10. "Monarto Co. Sturt".

*Holochila erinus* Fab. Miskin 1891 Annals Queensland Mus. 1 : 64-65 (part); Anderson and Spry 1894 Victorian Butt. (2) : 91 (pt.). (nec Fab. 1775).

*Candalides hyacinthina* Semper, Waterhouse 1903 Proc. linn. Soc. N.S.W. 28 (1) : 185 (pt); id 1903 Memoirs N.S.W. Naturalists Club 1 : 23 (pt). Rainbow 1907 Guide. . study of Aust. Butt: 127-129 (pt). (nec C. Felder 1862).

This is the earliest valid name for the collective species hitherto erroneously known as *hyacinthina* Semper 1878 (nec C. Felder 1862). Subspecies *simplexa* ranges from north-western Victoria through South Australia.

### CANDALIDES SIMPLEXA CYANITES (Meyrick) 1888. n. comb.

*Polyommatus cyanites* Meyrick 1888 Proc. linn. Soc. N.S.W. (2) 2 (4) : 828 "Geraldton, West Australia". *Holochila cyanites* Miskin 1891 Ann. Queensland Mus. 1 : 64: *Candalides cyanites* Waterhouse 1903 Proc. linn. Soc. N.S.W. 28 (1) : 186.

This is the subspecies from West Australia, distinguished by the broader black borders, the clearer, more brilliant blue shading of the discal areas, and the darker undersides of fore and hindwing in both sexes.

### CANDALIDES SIMPLEXA JOSEPHINA Harris 1952. n. comb.

*Candalides hyacinthina josephina* Harris 1952 North Queensland Naturalist 20 (103) : 33-34. text. figs. "Stawell, Victoria".

A population intermediate between *s. simplexa* and *s. cassythae* from a restricted area, which is very doubtfully of subspecific standing.

Specimens from Kiata, eighty miles north-west of Stawell are undoubted *s. simplexa*, while those from Gisborne one hundred miles east are of the eastern

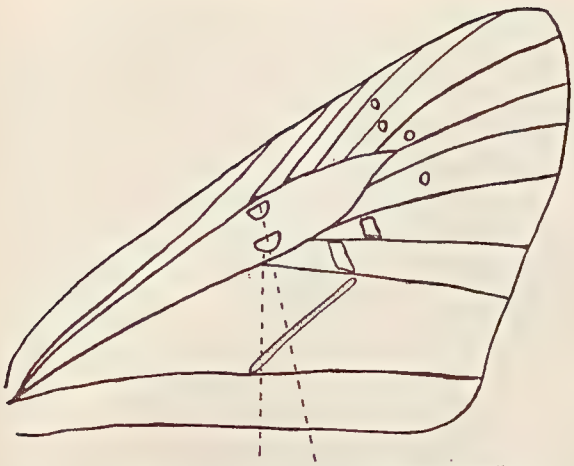


Fig. I *Pelopidas l. lyelli*

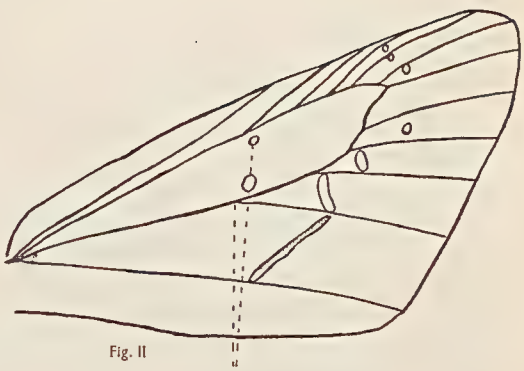


Fig. II

*Pelopidas agna dingo*

subspecies *s. cassythae*. The material on which the name was based was noted by the author as so variable as to suggest a hybrid population in a fringe area where two strong subspecies meet.

CANDALIDES SIMPLEXA CASSYTHAE (Scott) 1890. n. synon.

*Polycyma cassythae* Scott 1890 Australian Lepidoptera and their Transformations 2 (1) : pl. 12, figs. 1 (palpi), 2 (antenna), 3 (leg), female, underside, larva, pupa.

*Holochila hyacinthina* Scott, Semper 1878 Journal Mus. Godeffroy 5 (14) : 162, 190 (pt). "Sidney, Rockhampton". (Scott M.S.S. nec C. Felder 1862).

*Candalides hyacinthina* Semper, Waterhouse 1903 Proc. linn. Soc. N.S.W. 28 (11) : 185 (pt.) 2, f.20: 3, f.3. id 1903 Mem. N.S.W. Nat. Club 1 : 23 (pt.). Rainbow 1907. Guide . . . . study Austr. Butt : 127-129 (pt.) text f. 76-78 (transf.), 3, f. 8 female. Waterhouse and Lyell 1914 Butt. Australia: 80.17, f.338. 339. Grünberg 1921 in Seitz Die Gross-Schmett. der Erde 9:852 (pt.) Waterhouse 1932 What Butt. is that?: 131.18, f. 1A-1E (transf.); 19, f.6, 6A male and female.

*Chrysophanus erinus* Fab. Olliff and Forde 1890 in Scott Aust. Lepidoptera 2 (1) : 9(pt.) (nec Fab. 1775). *Holochila erinus* Fab. Miskin 1891 Ann. Queensland. Mus. 1 : 64-65 (pt.). Anderson and Spry 1894 Victorian Butt. (2) : 91 (pt.) text figs. *Candalides erinus* Fab. Druce 1902 Proc. zool. Soc. London 1902 : 120.

The invalid name first used for this species by Semper in 1878 has since been generally adopted by Australian authors, and its earlier use by C. Felder in 1862 for the allied species *erinus* overlooked. Felder lists "No. 169 *Holochila erinus* Fab. (*hyacinthina* Scott in litt) Ash Island" following his description of "No. 168 *Holochila absimilis* Scott in litt. Ash Island".

The name *hyacinthina* as used by Semper and subsequent authors therefore has no standing, it must be discarded and the collective species known by the earliest name, which is *simplexa* Tepper 1882. Fortunately Scott's name *cassythae* is available for the subspecies hitherto erroneously known as *hyacinthina* Semper. Scott's specimens came from Ash Island, in the Hunter River near Newcastle, which may be accepted as the type locality. The same form occurs throughout eastern Australia from central Victoria through coastal New South Wales to southern Queensland. The male above is brown tinged with purple, the termen of fore and hind wings bordered brown. Beneath the ground colour in both sexes is grey, distinctly lighter than the southern subspecies *simplexa*.

CANDALIDES SIMPLEXA EUGENIA Waterhouse and Lyell 1914. n. comb.

*Candalides hyacinthina eugenia* Waterhouse and Lyell 1914 Butt. Australia: 80.17, f.340, 341. "Kuranda. Atherton. Rockhampton". Seitz 1927 Die Gross-Schmett. der Erde 9 : 1114. Waterhouse 1932 What Butt. is that?: 131-132.

This, the smaller north Queensland subspecies is again lighter in tone of ground colour beneath than the eastern *s. cassythae*.

EVERES LACTURNUS AUSTRALIS nom. nov.

Pro *Everes argiades* Auct. (nec Pallas 1771); *Everes parrhasius* Semper (nec Fabricius 1793).

*Lampides parrhasius* Fab. Semper 1878 J. Mus. Godeffroy 5 (14) : 155-156, 190, 193 (on p. 190 Semper attributes the name *parrhasius* to Horsfield).

*Lampides argiades* Pallas. Miskin 1891 Ann. Queensl. Mus. 1 : 56-58.

*Everes argiades* Pallas. Waterhouse 1903 Proc. linn. Soc. N.S.W. 28 (1) : 219-220. id. 1903 Mem. N.S.W. Nat. Club 1 : 26. Waterhouse and Lyell 1914 Butt. Australia: 99. 17, f. 346, 347, 348. Tindale 1923 Trans. Roy. Soc. South Australia 47 : 353. Waterhouse 1932 What Butt. is that?: 166. 23, f.3, 3 A male and female.

Miskin, who seems to have been the first Australian author to use *argiades* for this species, gives a long list of names including several forms of the palaearctic species described by Pallas, as well as other species such as the American *comyntas* Godart and *lacturnus* Godart described from Timor, both now recognised as distinct. Semper, the first author to record the species in Australia, used *parrhasius* and it is difficult to understand why later authors did not follow him, but adopted the extremely unlikely South European species-name for this butterfly. Writers dealing with the species of the Indo-Malayan region (Seitz 1924 : 923; Evans 1927 : 143) had shown the distinction between *argiades* and the Indo-Australian "*parrhasius*". However, Toxopeus 1929 (Tijdschrift voor Entom. 72 : 227, 240) held that the Fabrician name could not be applied to an *Everes* species and used it for a species of *Nacaduba*. Corbet in 1938 (Trans. Roy. ent. Soc. London 1938 : 140) agreed that *parrhasius* could not be used for an *Everes*, but disagreed with its use for a *Nacaduba* species. Finally, in 1941 Corbet (Proc. Roy. ent. Soc. Lond. (B) : 102, 103) showed that *parrhasius* Fabricus, first applied to *Everes lacturnus* Godart and then to *Nacaduba nora* Felder, is to be used for a *Euchrysops* species from South India, so the name at last disappears from the Australian lists.

I have checked the 16 ribbed, elongate androconia of our species, fig. III, and find it agrees with the scales of the Indian "*parrhasius*" as described by Evans 1932 (Identification of Indian Butterflies ed. 2: 219).

The male of the Australian subspecies above is violet-blue bordered with black margins 1 mm. wide, the tornal spots of hindwing in areas 2 and 3 outlined with crescentic orange scaling. Beneath the ground colour is bluish-grey, the tornal patch of hindwing extending widely from areas 1a to 3 and sometimes to 4.

The female above is black, the tornal spots of hindwing in 2 and 3 crowned with pale orange crescentic patches. Beneath as in the male.

Both sexes differ from the Indo-Malayan subspecies *rileyi* Godfrey in their different colour above and in the broader, extended orange tornal area beneath which in subsp. *australis* is not bounded basally by a brown crescentic line.

Male forewing length 11 mm., female 12.5 mm.

Holotype male labelled Cairns, Q. Sea level. 20 April 1960. J. Kerr.

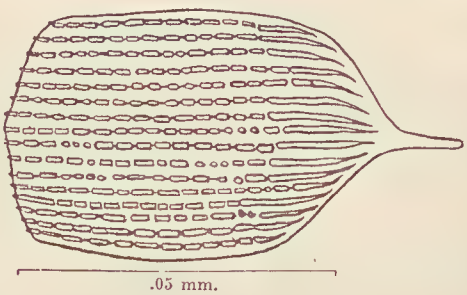
Allotype female, data as male. Types are in my collection.

This butterfly is very variable in size, I have seen a male labelled Meringa, N.Q. 3-6-26 A. N. Burns which is but 6.5 mm. in wing length, another male in the Burns collection from the same area dated 26-10-26 is 7 mm.

A female from Kuranda, Q. 17 April 1958 E. J. Harris in my collection is 9.5 mm. in wing length compared with another from the same district dated 19 April 1958 of 12.5 mm. The discal areas in northern females tend to be light grey-brown in colour compared with the black marginal areas. Male specimens from Brisbane and perhaps generally in the southern limits of its range have a lilac tinge in the blue of the upperside. A female in the Burns collection labelled Coramba, N.S.W. 26 Oct. 1947 F. P. Dodd has the area of forewing from hindmargin to disc coloured as in the male, the veins 1, 2 and 3 in the discal area of the hindwing are striated with the same bluish colour.

The subspecies ranges from Coramba in northern N.S. Wales through coastal Queensland to the Claudie River area, it has also been found on Groote Eylandt, at Darwin and in the Daly River district. I have records of it flying in the north in every month from September till June, in the south from October to April.

FIG III.—*Everes lacturnus australis.*




ZIZULA HYLAX ATTENUATA (Lucas) 1889. n. comb.

Corbet 1940 (Entomologist 73 : 276) advances evidence to show that the Fabrician *Papilio hylax* 1775, formerly wrongly applied to a species of Pithecops, replaces *gaika* Trimen as the name for the collective species.

PSEUDALMENUS CHLORINDA (Blanchard) [1848].

During the past fifty years quite a number of authors, Waterhouse and Lyell (1914), Waterhouse (1928), Burns (1948), Couchman (1948), Tindale (1953) have written more or less extensively about this unusually interesting butterfly, yet the initial problem of the origin of Blanchard's specimens continued to be unsolved. As I noted in 1948, the type specimen is no longer in the Museum d'Hist. Nat., Paris, and must be regarded as no longer in existence. Fortunately further study could be based on the very good figure of male and female upper and undersides given in the Atlas of plates to D'Urville's Voyage au Pôle Sud, the text to which gave merely "Tasmanie" as the type locality.

It has been generally agreed, since Waterhouse wrote in 1928 "I consider the types came from near Hobart," that the original specimens were taken, or acquired, during the stay of the French ships of war "Astrolabe" and "Zélée" in the Derwent between December 13, 1839 and January 2, 1840.

Again, authors from Waterhouse to date have admitted their lack of material from Hobart (I exclude Kingston and Snug specimens for reasons given later) while basing their writings on specimens from elsewhere in the island.

After years of searching for this species, the fortunate discovery by my friend A. M. Hewer of a colony near Richmond in 1954 which gave specimens matching the original figures suggested that at last the area had been found from which the French naturalists obtained their specimens.

Since at the time of the French visit, travel to Richmond and beyond to Port Arthur was more usual than in the direction of the D'Entrecasteaux Channel area, the accounts in the text of the "Histoire du Voyage" mention Richmond but have nothing of visits to the Channel districts; these reasons, with the lack of agreement between Channel area specimens and the Blanchard plate, convinced me that the French specimens had been obtained on the eastern shores of the Derwent, although no specimens from this area were to be found in any Australian collection.

## HISTORICAL EVIDENCE.

The arrival of the Astrolabe, Mons. Dumont D'Urville, and the Zélée, Capt. Jacquinot, each of ten guns and out twenty-one months from Toulon is reported in the Colonial Times of December 1839, and also in the Hobart Town Courier and Van Diemen's Land Gazette of Friday evening, December 13, 1839, and their departure, on January 2, 1840, is reported in the latter newspaper of Friday evening, January 3.

The True Colonist of December 20, 1839, in its Shipping News also reports their arrival and in the Weekly Report of Ships in Harbour has the following significant comment: "The above named ships are on a voyage of discovery and have put in here to recruit the health of their crews and refit". It is to be noted that the Astrolabe and Zélée had left Toulon on September 7 1837 and during the intervening months had crossed the Atlantic, rounded Cape Horn, crossed the Pacific, visiting many islands en route as far north as Truk, thence around the New Guinea and North Australian coasts and Java down to Hobart, so naturally the dreaded scurvy had taken its toll of the crews.

Incidentally, Murray's Review of December 31, 1839, has a note of the "meritorious conduct" of officers and men of the French ships in dealing with a fire in a sail loft, regretting the fact that "unfortunately local residents also fighting the fire directed their hose on the invalid strangers, drenching them".

Thanks to the kindness and co-operation of the State Archivist, Mr. P. Eldershaw, my wife and I were able to see two important letters bearing on the problem. The first, in copper-plate handwriting, dated "Astrolabe 30 December, 1839" and signed J. D'Urville, is addressed to the Governor of Van Diemen's Land, expressing thanks for "hospitality received during the visit of the Mission under my command" and "requests to leave 'quinzaire de maladies' under the supervision of Mr. Hombron, Surgeon-Major of the Expedition, for a period of two or three months" when Captain Jacquinot would return for them.

D'Urville continues with requests for consent for the sick men to remain in his absence, for a continuation of medical treatment under the authority of Mr. Bedford, for financial assistance to Mr. Hombron during the stay of the sick men and finally (in case of D'Urville's non-return from the Antarctic), a request that the sick men be transferred to Mauritius at the first favourable opportunity, promising the expense would be paid by the "Royal Treasury of the French Navy". The second letter, dated from Government House 10 January 1840 signed J. Franklin and addressed to the Marquis of Normanby, reports on the visit of the ships and "the 17 men left in the Colonial Hospital", together with D'Urville's requests.

Although the official account of the voyage makes little mention of illness, other than D'Urville's direction to M.M. Hombron and Ducorps, on arrival, in Hobart Town, "to establish a provisional hospital in order to carry there our sick men", that it was regarded very seriously by the locals is shown in the True Colonist of March 6, 1840, where in an article headed "The Fever" we read . . . "There is a great deal of murmuring among the inhabitants arising from a very general belief that the disease, typhus fever, has been introduced into the Colony by the French discovery ships, and there is a general complaint against the Government for not having placed them under quarantine in place of allowing them to establish a lazarhouse in the very centre of the town". A further note continues . . . "It is not correct that it broke out first at Richmond, the disease was first carried there, or rather to Malcolm's Huts, by some men who had been removed from Hobart Town. All the sick have now been removed from that station, and from Richmond, to the station at Grass Tree Hill, where the chapel, a fine airy building, has been converted into a hospital for their reception".

In the official "Histoire du Voyage", D'Urville, on page 69 notes "On my return to Richmond I met again the men who were fully convalescent, but some had been very sick and were getting better little by little", though the True Colonist of 28 February under a note of the sailing of the French ships says "the above ships re-embarked their invalids, left at Hobart Town".

The clue to the evident confusion is given by the above issue of the True Colonist, where it speaks of the French Seamen "suffering from diarrhea and inflammation of the intestines", the prison gangs from "typhus fever", in fact it notes, during an account of the visit of Sir John and Lady Franklin to Richmond, the "great mortality from typhus fever".

It is clear that the local inhabitants, confusing scurvy and its effects with the outbreak of typhus fever and holding the French responsible for the latter, by their clamour, forced the evacuation of J. B. Hombron and his charges from Hobart Town to Richmond and eventually to Grass Tree Hill, into the very area which today produces specimens of *c. chlorinda* comparable with the French types.

It is of course true that a number of members of the French expedition, in addition to J. B. Hombron, collected insects, as Musgrave (1932: 73-74) points out, but Hombron's prolonged stay in and near Hobart Town provided him with the opportunities for amassing the collection which he,

in collaboration with his fellow-surgeon, H. Jacquinot, were to describe when they later jointly supervised the zoological parts of the *Voyage au Pôle Sud*. The whole of the historical evidence available shows that the French naturalists were well acquainted with the eastern shore of the Derwent, particularly the Richmond district, so reinforcing the evidence provided by collected material.

## COLLECTED MATERIAL.

Although Waterhouse (1928) gives a coloured figure of a male, from Launceston, which he says is "very close to the figure" of Blanchard, no specimen had been exactly matched to the original plate by any author when my attention was first directed to the species almost twenty years ago. J. R. Cunningham in 1948 and subsequent years had specimens from Kingston and he and I bred a number of specimens of both sexes from this locality, until the solitary *Eucalyptus* harbouring the butterfly was destroyed several years since. All the specimens from there were quite different from the original figures. When, however, the first Richmond specimens were bred in 1954 I immediately recognised their likeness to the Blanchard originals, and my fig. 5 is of a male which almost exactly matches the type male (Blanchard's plate 3, fig. 15, 16) above and beneath. The latter plate shows a specimen with a triangular patch of thinly scattered orange scales between the cell and discal spot, although this discal area may be thinly scaled I find it is rarely so clearly coloured as in Blanchard's fig. 15.

During the 1954 season more than thirty males were reared from the pupa or caught flying, the darkest is completely black except for a few scattered yellow scales on the forewing beyond the cell bar and in the discal area of space 1b; the deep orange-red tornal band of the hindwing extends narrowly into area 3. Average forewing length 14.5 mm.

The lightest male has three small orange spots, each 2.5 mm. square, one bordering the cell bar, the other two in the discal areas 1b and 2. This latter is indeed an unusual specimen from this area, for collecting in this and subsequent years has produced only three similar examples, the rest are without exception as dark or darker than the Pôle Sud figures on the upper side. Actually Waterhouse's claim for his 1928 figure 1 is not well founded, it lacks the two clear orange spots on the forewing, and the tornal band of the hindwing is too broad and does not taper away thinly in areas 2, 3.

The female which I figure from Richmond is again very close above and beneath to the Blanchard plate 3, figures 17, 18. Waterhouse and Lyell's figure 864, which Waterhouse (1928) claims is close to the original, has the tornal band of hindwing above extending far into area 6, quite unlike the narrow tapered band of the original figure and of my specimen. In fact all Waterhouse's figures confirm their origin, they bear the characteristics of Launceston specimens bred or caught within the past fifty years by a number of collectors, notably F. M. Littler and my friend G. H. Hardy, who has helped me with his recollections of this species in its northern habitat during the period 1913-1918.

One marking I find that has been completely overlooked by previous writers, is the sub-basal black streak extending to a variable degree along vein 1b of the underside forewing. The conventional mode of setting normally covers this marking, but I find it present in all Tasmanian specimens.

Reverting to specimens from the opposite shores of the Derwent, experience confirms Waterhouse's remarks (1928: 411) regarding his males from Snug, that the males above have the forewing broadly marked, and the hindwing with conspicuous central patch and extended tornal band. The figure given by Tindale (1953: pl. 20, f.d.) is unusual in that it does not agree with the material from this area caught and bred by J. R. Cunningham and myself over a period of years, usually males approximate to or are even more broadly banded than Waterhouse's 1928 fig. 3, with which Waterhouse compared his Snug specimens. Kingston females also have the forewing more broadly banded and the hindwing with a larger central patch and broader, more extended tornal band than any specimen from the eastern shores taken over a period of seven years.

I believe I have shown that specimens from the eastern shores of the Derwent are the only ones consistently agreeing with the original Blanchard plate, and this, together with the historical evidence I have adduced above, confirms that Richmond near Hobart is to be regarded as the type locality and I so designate it, selecting the figured examples in my collection, as neotype male and female to replace those specimens figured by the French expedition, now no longer in existence.

In other areas of east and north Tasmania from which *c. chlorinda* has been seen or obtained the specimens show rather remarkable differences. With the exception of material from two areas, one south of Orford, the other west of the Derwent, all specimens show a definite trend towards the Victorian ssp. *zephyrus*. In the majority of males the spots of the forewing upper side form a distinct band across the disc, while the tornal band of hindwing above is broader, extending at least to vein 5, frequently beyond, and does not taper off thinly as in males from Richmond. Waterhouse (1928: pl. 25, f. 3) illustrates these characters well.

Females above invariably possess a more or less conspicuous central orange patch in the hindwing (this is not true of Richmond females) while, as in the males, the tornal band extends around the hindmargin and does not taper thinly away. Waterhouse and Lyell's figure 864, a female from Launceston, is a good representation of the majority of females from eastern and northern Tasmania.

It is not very difficult to separate Richmond specimens by one constant character, the distinctly dull grey tint of the ground colour beneath. Other characters advanced by authors for separating Tasmanian specimens (Waterhouse 1928, Tindale 1953), such as the greater or lesser extent of the orange band of the forewing upperside or the presence or absence of a discal row of black spots on the hindwing beneath completely break down in both sexes now that I have been able to examine more than one hundred specimens from many localities. For example, in an unselected series of 24 males from Richmond, 12 have no trace of the discal row of spots beneath, the proportion

is even less in a smaller series of females. I find this true also of specimens taken near Launceston.

Examples drawn from the western shores of the Derwent and particularly those from a locality south of Orford complicate the distribution pattern greatly. Males from the Kingston-Snug areas are quite as clearly banded on the forewing as any in a series of forty specimens from Victoria caught and bred over a long period of years which were kindly presented by my friend C. G. L. Gooding, and the hindwing has the clear central patch and comparatively broad tornal band extending beyond vein 5 exactly as in ssp. *zephyrus*. In size both males and females from these districts closely approximate the Victorian race. In an area south of Orford, extending towards the Forestier Peninsula occurs a still larger, more extensively marked population than any Victorian *zephyrus* I have examined. The females with an average wing length of 17.5 mm. in 16 examples are notably larger and brighter, approaching, even to the ground colour beneath, the N.S. Wales race *chloris* as figured by Waterhouse and Lyell (1914: pl. (42) f. 870, 871).

Consideration of these populations and the problems they present is deferred for further study.

The life history in Tasmania differs again from the published accounts (Waterhouse (1932); Burns (1948); Tindale (1953)) in several features. For years my friends, my wife and I searched scores of *Acacia melanoxylon* for larvae or pupae of the butterfly, but not once did we find any trace. Then some twelve years since J. R. Cunningham found larvae on *Acacia dealbata* at Kingston, and subsequent experience in half a dozen areas has confirmed that either *A. dealbata* or, more rarely, *A. mollissima* are the sole food plants in Tasmania, not *A. melanoxylon*. The latter tree, whether in isolated groups in the south-east, or the extensive stands of the north-west, does not harbour the butterfly.

Further, the butterfly is always associated with the small black "stink-ant", *Iridomyrmex foetida* and again, the ant, in my experience, is usually associated with *Eucalyptus viminalis*, more rarely with *E. globulus* or *E. obliqua*. *Pseudalmenus chlorinda* has been found where the foodplant is at all stages, from a few inches to ten or fifteen feet high, the former especially where the trees have been cut down for "wattle-bark", but even if the *Acacia* be ten feet or more from the nearest ant-infested *Eucalyptus viminalis*, pupae of the butterfly have been found beneath the bark of the latter tree, always attended by numbers of *Iridomyrmex*. Ova and, of course, larvae, have been found on both species of *Acacia*, but no pupae have been detected away from the masses of ants on the *Eucalyptus*.

## SATYRIDAE.

### OREIXENICA PALUDOSA THEDDORA Couchman 1953.

When describing this new subspecies in 1953 (Proc. Roy. ent. Soc. Lond. 22 (5/6). 76-77) I had seen only three males, all taken by the late F. E. Wilson, near Lake Catani on Mt. Buffalo at an altitude of about 4,400 feet. Subsequently, many more males and some females have been obtained through the persistent efforts of my friend D. F. Crosby, accompanied by J. Landy and the late F. E. Wilson. A number of males was taken in February-March, 1956, but not until March 1958 were the first females secured. These, together with other specimens taken in March 1960 are now before me. All were obtained on the plateau of Mt. Buffalo and my friend informs me that it was possible to concentrate on *p. theddora* to the exclusion of the large numbers of *lathoniella herceus* since the two species prefer different types of locality: *p. theddora* occurs only on the plateau which varies from about 4,100 to 4,500 feet, and not down the slopes of the mountain as does *l. herceus*.

Female: larger, the ground colour (Capucine Yellow Ridgway 3) lighter in tone than ssp. *nama* Couchman, approaching the colour of ssp. *latialis* W. and L. female, but differing from the latter in its far greater size. Costa very slightly bowed, termen evenly rounded so that the forewing is relatively much broader than in either ssp. *nama* or *latialis*.

Upperside forewing; costal area narrowly cream, cell bar and discal band black, other markings Mummy Brown (Ridgway 15); cell bar and discal band not joined, the latter connected by a brown streak along vein 2 to terminal band, a brown streak along vein 3 from terminal band approaches discal band, the terminal band enclosing a small yellow spot in area 3; basal brown area extending along costa, as in holotype male, joining cell bar discal and terminal bands and also extending from base along dorsum to discal band; terminal band broad, leaving ground colour only as small crescentic spots in areas 3 to 7. Apical ocellus, with minute white pupil, black, 2 mm. diameter, surrounded by yellow ring.

Hindwing markings Mummy Brown (Ridgway 15) broadened and extended so that ground colour appears only as spots, one in cell based on vein 4 a curved discal series from costa to tornus and a post-discal series of crescentic spots from areas 2 to 6; tornal ocellus with minute white pupil, black 2 mm. diameter, surrounded by an orange ring and brown line.

Beneath: Forewing markings as above, but clearly defined only along costa, merging into ground colour in discal area. Costal and apical area broadly cream, post-discal crescentic silver spots extending from costa to area 3; a subapical ocellus surrounded by cream ring.

Hindwing: Basal two-thirds dusted with greenish-yellow scales, basal, discal and sub-marginal silver spots as in male, cell spot with straight upper edge based on vein; sub-apical and sub-tornal ocelli minutely white-pupilled, black, 2 mm. diameter, each surrounded by a yellow ring and brown line.

Length of forewing 18.5 mm., width 10 mm., in ten specimens measured the length varied from 17.5 mm. (2 specimens), 18 mm. (4), 18.5 (3), to 19 mm. (1 specimen).

There is some variation in marking in this series of females and in examples captured subsequently, but it follows the type of variation usual in the genus. Three specimens have a minute black dot in area 3 below sub-apical ocellus; several have an upward extension of this ocellus almost forming

an extra spot; two specimens have a sub-apical black spot on hindwing above, and in one example the ground colour is clear Orange (Ridgway 3), with costa broadly cream and with narrow brown markings. The discal band extends completely across the forewing in two specimens, being joined by an extension of the basal brown area from dorsum, reminiscent of the pattern of *O. lathoniella* f. *maweena* Couchman, but the band is not of even width as in that species and *p. theddora* can always be distinguished by the distinctive brown streaks connecting discal and terminal bands along vein 2.

Neallotype female labelled "Lake Catani, Mt. Buffalo, Vict. 10 March 1958. D. F. Crosby", with three paratypes in my own collection, six paratypes returned to the collector. The series was taken at an altitude of circa 4,300 ft.

HETERONYMPHA CORDACE (Geyer) [1832].

Further intensive collecting since my last note (1954) on the races of this species in Tasmania has added to our knowledge, several trips undertaken with the help and co-operation of my friend K. M. Dallas have helped to define the limits of the three subspecies found in the State.

H. CORDACE COMPTENA Couchman 1954.

Male specimens taken again last year at Dover confirm the limits of this western and southern race, which has not been found nearer Hobart. It was however a complete surprise to meet with this subspecies at Lunawanna on South Bruny Island. In January 1959, my wife and I were able to take six newly emerged males in an area over which we had collected for a number of years. A later visit on the 15th February produced two very worn females and a remarkable male aberration in which the forewing markings above are confined to a faint cell and discal spot on the costa, beneath all markings are faint and blurred.

A few days' survey of the Mt. Agnew area near Zeehan in January 1960 disclosed that ssp. *comptena* occurred there from near the sea shore at Trial Harbour to the site of the former Cumberland Dam at about 1300 feet altitude, in the latter area four males and a female were found at the head of a very moist gully opening out on the heathlands on the shoulder of the mountain, in the only spot sheltered somewhat from the full force of the westerly gales. The northern limit of this race on the West Coast is not known, the boundary may well be the Pieman River, but a single male seen but not captured this year north of the Arthur River remains our only knowledge of this butterfly in the north-west, an extensive search of the heathlands between the river and Marrawah failed to yield another, so that it must be very rare there.

H. CORDACE LEGANA Couchman 1954.

Again thanks to my friend K. M. Dallas who provided transport and companionship, during January 1959 a long survey of the north-eastern districts was undertaken. Ssp. *legana* was first found five miles east of Storey's Creek at an altitude of about 2000 feet, close to the water-races of abandoned tin-mining operations. On the slopes of Mt. Saddleback at about 2,500 feet a pair was taken and on the Mathinna Plains a few miles south of Ringarooma at about 2,600 feet a number of males were found. The same form was also taken near Moorina, and a single male, labelled "5 miles N. of Lilydale, Tas. 10 Jan. 1955. A. M. Hewer" extends the range of this race still further west in the direction of the Tamar River; all are clearly of the sub-species first described from Lake Leake and now known to be found in a number of localities in the north-eastern portion of the State. A worn male and two females taken almost on the roadside on the Blue Tier at about 2,100 feet north of St. Helens however, while retaining the extended light ground colour usual in ssp. *legana* in the females have the subtornal ocelli of the hindwing reminiscent of the western ssp. *comptena*.

H. CORDACE KURENA Couchman 1954.

The range of this central Tasmanian race was extended when specimens were secured at Miena and Breona, 3,400 feet, in January this year; males and females agreeing with the form described from the Cuvier River-Lake St. Clair district further west. However, passing from this area towards the north-west the opportunity was taken to collect around St. Valentine's Peak, thanks to the ready permission granted by the A.P.P.M. Co. to use their private roads.

A short series of males and three females was obtained at about 2,000 feet in company with *Heteronympha penelope panope* Waterhouse and a dwarf form of *Oreixenica lathoniella lathoniella* Westwood. These specimens, like a few males and two females from the banks of the Emu River at Hampshire, altitude 1,520 feet, which approach them closely, are by far the darkest form I have seen. The ground colour above is lighter, but restricted by the expansion of all the black markings on fore and hindwing to narrow yellow bands. Beneath, the hindwing, particularly the basal area and the dorsum, is darker than in any other specimens seen even from northern New South Wales. A single male, taken on the same day a few miles further west on the Wandle River, at about 2,000 ft., has the hindmargin of both wings completely black.

The north-western plateau area obviously contains material in this, as in other species, for further research.

**ACKNOWLEDGMENTS.**

My thanks go to many friends whose enthusiastic collecting continues to extend and increase our knowledge of the Australian *Rhopalocera*.

Dr. J. Kerr and Mr. E. J. Harris have greatly helped with specimens from Queensland, Messrs. K. M. Dallas and A. M. Hewer have provided transport and afforded companionship during many collecting trips to remote places in Tasmania Messrs. S. Angel and D. F. Crosby have freely loaned material for study, their frequent and frank discussions have helped clarify many lepidopterological problems, while I am particularly indebted to the latter for photographs of a number of original figures.

I am very appreciative of the fact that much of my work could not have been accomplished without the ever-ready co-operation and assistance afforded by my friends in the National Museum of Victoria and the Australian Museum, Sydney. The late

A. (Tony) Musgrave, whose recent death left a sad gap in the ranks of Australian entomologists, had an unrivalled knowledge of the literature of the subject, and for more than thirty years gave me unstinting help and inspiration. The Director of the National Museum, C. Brazenor, and the Curator of Insects, A. N. Burns, together with the staff of the Entomological Dept., have aided my research work in every way, and I am grateful indeed for their interest in the cause of scientific research.

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PLATE.

FIGS. 1, 2.—*Oreisplenus munionga larana* n. ssp. Marrawah, Tas. Sea-level. 26-Jan.-1961. Holotype male; upper and underside.

FIGS. 3, 4..—*Oreixenica paludosa theddora* Couchman. Lake Catani, Mt. Buffalo. Vict. 4,300 feet. 10-March-1958. Neallotype female, upper and underside.

FIG. 5.—*Pseudalmenus chlorinda chlorinda* Blanchard. Richmond, Tas. 200 feet. 18-Sept.-1954. Bred x pupa. Neotype male, upperside.

FIG. 6.—*Pseudalmenus chlorinda chlorinda* Blanchard. Richmond, Tas. 200 feet. 24-Sept.-1954. Bred x pupa. Neotype female, upper side.

FIGS. 7, 8.—*Everes lacturnus australis* n. ssp. Cairns, Queensland. 20-April-1960. J. Kerr. Holotype male, upper and underside.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

# RECORD OF THE OCCURRENCE IN AUSTRALIA OF LIGIA EXOTICA ROUX (CRUSTACEA, ISOPODA, ONISCOIDEA)

By

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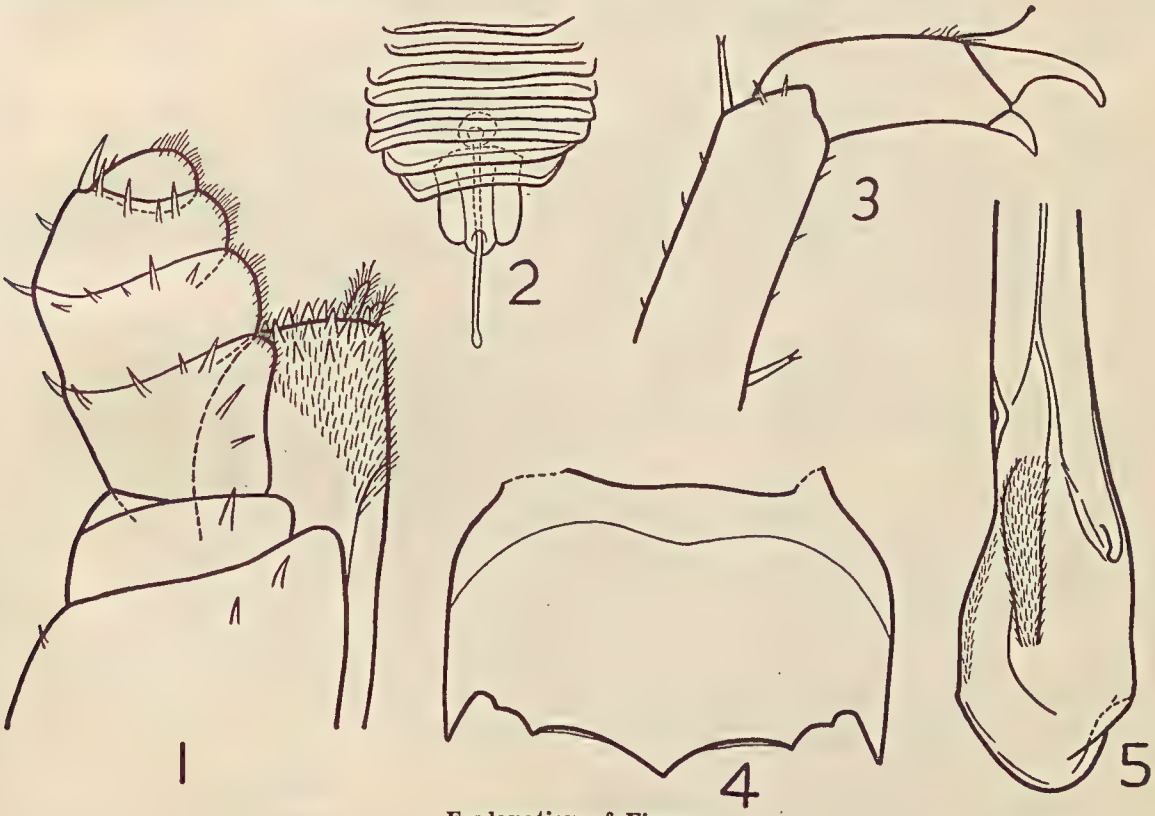
## INTRODUCTION

In all but one instance, examples of genus *Ligia* Fabricius recorded from Australia to date have been assigned to *L. australiensis* Dana, 1853. The one exception is a record by Jackson (1922, p. 697) of *L. novae-zealandiae* Dana, 1853, from Sunday Island, Victoria. Specimens of *Ligia* from Bobbin Head, New South Wales, which were presented to me by Dr. J. le Gay Brereton, differ from both of these species. A comparison of their characters with the descriptions of *L. exotica* Roux, 1828, given by Chilton (1916, p. 462), Jackson (1922, p. 693) and Verhoeff (1928, p. 116) shows that they should be assigned to *L. exotica*.

The following description serves to confirm the identification and to outline significant characteristics of the specimens.




**Explanation of Figures**

*Ligia exotica* Roux.

Fig. 1.—Distal part of right maxilliped, ventral view.
Fig. 2.—Scale-seta on a granule on 2nd tergite of pereion, dorsal view.
Fig. 3.—Distal part of propodos, and dactylos, of left 1st leg of male, anterior view.
Fig. 4.—Terminal segment, dorsal view.
Fig. 5.—Distal part of endopodite of left 2nd pleopod of male, dorsal view.

*Ligia exotica* Roux.

(Figs. 1-5.)

SYNONYMY.—*Ligia exotica* Roux, 1828, p. 3, pl. 13, fig. 9. *Megaligia exotica* Verhoeff, 1926, p. 348.

Further synonymy given by Jackson (1922, p. 693) and Van Name (1936, p. 48).

*Male.*

*Size.* Length of largest specimen, 20 mm., breadth, 7.5 mm.

*Cephalon.* Eyes separated by less than breadth of each eye; distance between inner angles of eyes, 1.3 mm., horizontal breadth of eye, 1.4 mm.

*Second antenna.* When attached, antenna extends backwards as far as postero-lateral angle of terminal segment. Length of peduncle, 8.2 mm., length of (right) flagellum, 12.8 mm. In largest male, number of articles in flagellum 39 in left appendage, 37 in right. Variation in number of articles among all six males, 32-39.

*Second maxilla.* A definite division of distal part into two lobes. No setose processes.

*Maxilliped* (fig. 1). Ischion and dactylos completely distinct; suture lines dividing meros, carpos and propodos complete across ventral surface but incomplete on dorsal surface, where they extend only part way across from inner border. Endite with two conical setose processes on inner side of its apical border, and teeth set at four different levels across its ventral surface near apex; distal part of endite densely setose.

*Pereion.* Coxal suture lines evident on 2nd-7th segments. Dorsal surface distinctly granulate. On each granule is a scale-seta (fig. 2) having a trilobed scale portion and a long seta, clubbed at apex. Broad hyaline scales overlap base of scale-seta.

*Pereiopods.* No process developed on distal end of propodos of 1st leg (fig. 3). First to third legs not subchelate, i.e., propodos and dactylos not strongly bent back under carpos. On inner side, near lower border, of both meros and carpos of 1st-3rd legs is an area covered by serrated ridges. Dactylar seta of 1st-7th legs clubbed at apex (see fig. 3).

*Male organs.* Evenly tapering to an acute apex. When attached, male organs do not extend back as far as posterior border of exopodite of 2nd pleopod; they lie free from endopodite of 2nd pleopod.

*Pleon.* Not abruptly narrower than pereion. Terminal segment (fig. 4) triangulate with median process acute, inner and outer accessory processes angular, and postero-lateral processes acute and extending backwards slightly beyond inner accessory processes. Dorsal surface of pleon granulate, scale-setae like those on pereion.

*Second pleopod.* Length of articles of endopodite: 1st 1.12 mm., 2nd 3.25 mm. Apical part of 2nd article (fig. 5) expanded, bluntly rounded at the end, and forming two small lobes on inner side. A wide groove extends down ventral surface of article to near apex where it becomes abruptly shallower. On dorsal surface of expanded part, towards outer side, is a semi-cylindrical protuberance covered with anteriorly-directed setae. A band of similar setae occurs near outer border. Anterior to this is a small chitinous thickening in outer border. Level with anterior half of setose protuberance, and near inner border of article, a hyaline thickening is formed in dorsal surface. Anterior to these structures, dorsal surface exhibits several ridges.

*Uropod.* Length of articles: prototype 5.1 mm., exopodite 8.6 mm., endopodite 8.3 mm.

*Female.*

*Size.* Length, 15 mm., breadth, 6.5 mm.

*Second antenna.* When attached, antenna extends backwards to middle of 5th segment of pleon. Length of peduncle, 6.4 mm., length of flagellum, 8.2 mm. Number of articles in flagellum 32 in each.

*Pereiopods.* No areas of serrated ridges on 1st-3rd legs.

*Uropod.* Measurements not available as no uropods atached to body.

*Habitat.*

Description is based on specimens collected by Dr. J. le Gay Brereton, at dusk on 1. IV. 1956, from a wall and rocks near salt water at Bobbin Head, New South Wales; six males and one female obtained.

## VARIATION FROM OTHER DESCRIPTIONS

A characteristic process on the propodos of the 1st leg of the male in *L. exotica* was described and figured by Chilton (1916, pp. 464, 470, fig. 11) and Verhoeff (1928, p. 117, fig. 24), and described by Jackson (1922, p. 694). No such process is developed in any of the six males in my possession. However, Chilton (p. 473), referring to specimens from Honolulu which he assigned to *L. exotica*, mentioned that in some of the younger males the process was small and hardly distinguishable. He suggested that probably it is developed to a full extent only in fully mature males. As the length of the largest specimen from Bobbin Head is 20 mm., as compared with lengths of 22 mm., 27 mm., and "about 30 mm." noted by Chilton, Jackson and Van Name (1936, p. 49) respectively, it may be that the absence of the characteristic process in my specimens is due to comparative immaturity.

## REMARKS

Dana (1853, p. 740) gave only a brief description of his species *L. australiensis*, which was based on a specimen collected in New South Wales. However his account is sufficient to exclude the possibilty of his having named as *L. australiensis* an example of *L. exotica*. In particular, Dana's figure (pl. 49, fig. 3) shows the terminal segment of *L. australiensis* with postero-lateral processes not extending backwards as far as the inner accessory processes, outer accessory processes not developed, and the posterior border forming a very blunt median angle; none of these features agrees with the form of the terminal segment in *L. exotica*.

## Acknowledgments

I should like to thank Dr. J. le Gay Brereton, Department of Zoology, University of New England, for his specimens of *L. exotica*.

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# FURTHER DISCOVERIES OF ABORIGINAL ROCK CARVINGS IN TASMANIA

by

OWEN W. REID

(With six figures.)

The Remarkable Cave Area, south of Port Arthur on Tasman's Peninsula, now a tourist attraction, was once frequently visited by the aborigines. The locality is of interest geologically as the molten rock in the form of dolerite was forced into horizontal layers between the sedimentary rocks of Triassic Sandstone. This horizontal action formed a sill. At the same time some molten rock found its way into vertical cracks creating a dyke. The molten rock baked the sedimentary rock coming in contact with it causing it to be metomorphosed. It was this baked rock that the aborigines used for the manufacture of many of their artefacts.

In 1950, accompanied by my son, I set out to investigate an aboriginal workshop and midden on the western side of the Remarkable Cave opposite the stairway. Due to a high tide and heavy southern swell it could not be approached from the cave. We, therefore, climbed a steep hill above the gulch where the sea pounded in, and forced our way through a ti-tree gutter, dense bracken ferns up to six feet in height and masses of stinging nettles, on to a ridge at the lower end of which was the workshop and midden. To make progress more difficult there were extensive areas of dense shrubs among the undergrowth lying parallel to the ground about knee high.

The workshop site is on a sandy ridge or small promontory, the less solid parts of which are being blown away or slipping into the sea. The "blown" area revealed a considerable number of flakes of baked sandstone up to twelve inches in length. Some showed evidence of chipping, while others were in their natural state. Very small chipping flakes were plentiful. The best specimens were two discoidal scrapers three inches in diameter pounding stones and a hand axe. On the returning climb traces of rock engravings were seen. As portion of the figures appeared to be covered with earth and leaf mould we returned next day with a spade and removed an overburden of approximately six inches to reveal a maze of carvings.

Like those near Billy Blue between Nubeena and Roaring Beach, the method of production appears to have been the grooving and scraping technique. However, unlike those at Billy Blue where the workings have been made on large flat surfaces, these near the Remarkable Cave are generally on undulating or vertical surfaces. Scarcely any of the heavily engraved areas exceed six feet in width. The vertical faces would be easily worked by an aborigine standing on the ground.

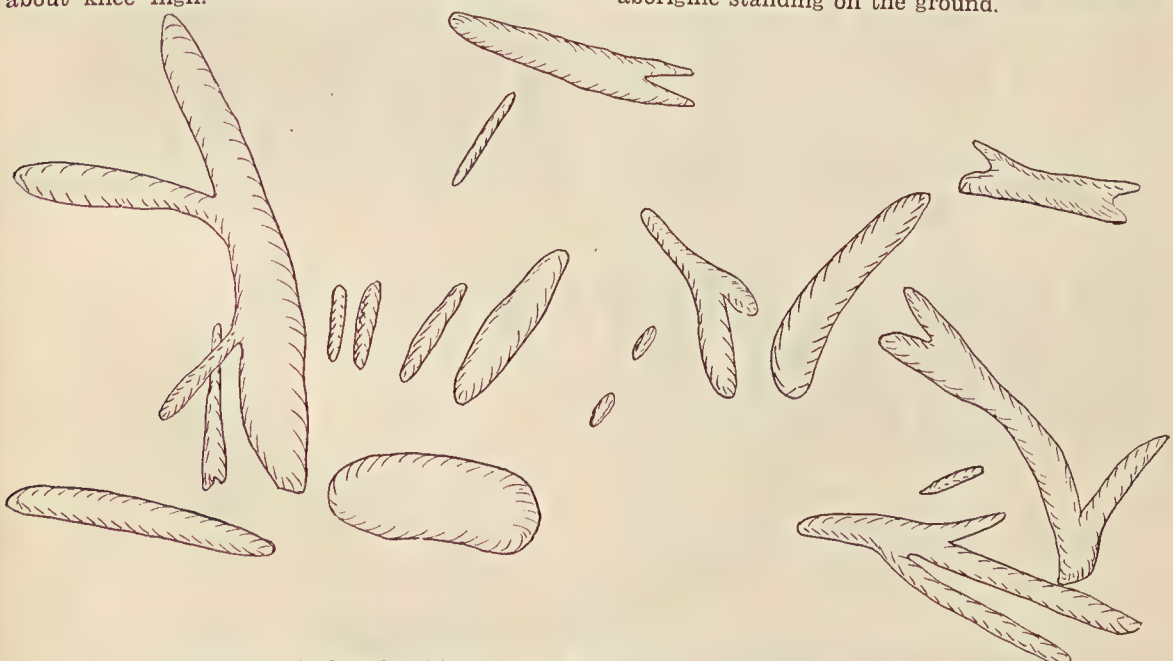

Fig. 1.—Bird and animal tracks. The figure on the left may be a kangaroo. It is 6 inches in length.

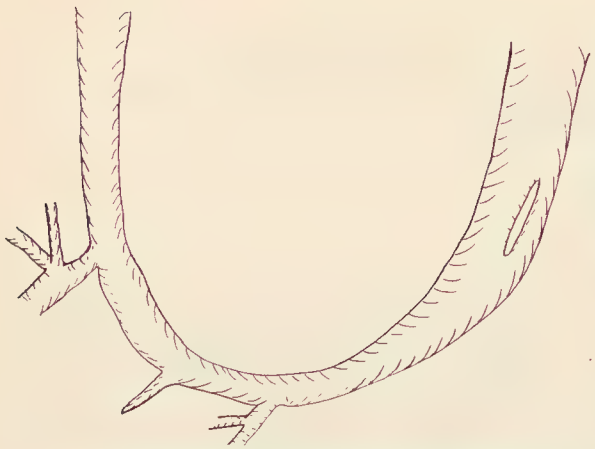

FIG. 2.—A semi-circular figure common among early stone age patterns. The diameter is approximately 10".

The actual figures vary in depth from a slight depression to two inches while the width ranges from mere scratches to an extreme of three inches.

On some of the more easily accessible surfaces it would appear that some figures had been superimposed upon others. Prominent among the engravings are emu tracks approximately six feet in length.

An interesting figure bore a strong resemblance to an ancestral animal pad having five toes found in the Carnarvon Ranges and recorded by R. H. Goddard. This pad had three toes each 2 inches, 2½ inches and 1½ inches respectively placed in relationship to a ball 2 inches in diameter. The depth of each was a quarter of an inch.

Two figures, approximately 16 inches and 18 inches in length, 1½ inches in width and 2 inches deep, appeared to be waddies or digging sticks.

Bearing a strong resemblance to the figure of a human leg and foot, recorded at Billy Blue near Nubeena, is a figure three feet long on a steep rock face.

There are hundreds of figures scattered over about a dozen rock faces in this area. On some of the more exposed surfaces exposure to the weather is having an eroding effect.

*The Broad-Derwent Rivers Junction Areas.*

Situated at, and just below the junction of the Broad and Derwent Rivers, three miles from the Ellendale-Dunrobin Road, the area holds particular interest. It is a few hundred yards below a dolerite intrusion. The swift-flowing Broad River, with its cool, crystal clear water enters the Derwent through a shallow valley. This river valley is interesting because on its descent from the National Park Area there is evidence of glacial action.

FIG. 3.—These figures resemble the recording of a corroboree.

Aboriginal rock carvings I found on large sandstone rocks bordering the river and on a ledge immediately above the strongly flowing stream. These I first found in 1957. Subsequent searches revealed further figures.

It is known that large numbers of aborigines inhabited this area. This was reported by Dr .Ross in the records of his visits to the Ouse district. Bonwick further supported this evidence by describing corroborees about which he had written. These aborigines would most likely be members of the Big River Tribe.

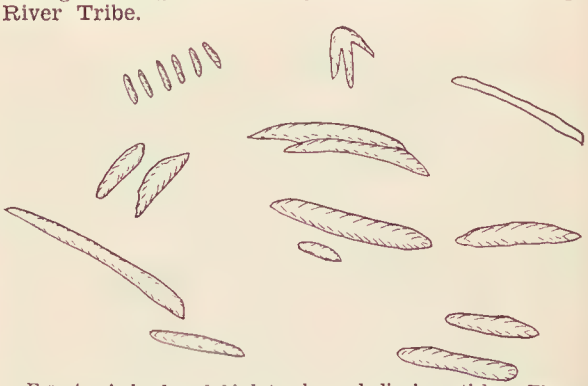

FIG. 4.—Animal and bird tracks and digging sticks. The longest figure is 12" long and ¼" deep.

Stone implements are to be gathered in quantity throughout the locality. All along the river banks nosed scrapers, flake knives and concave scrapers are to be found. In a rock shelter near the junction a chipped water-worn pebble in the form of a hand-axe was collected. This variety of evidence of aboriginal occupation either for food gathering, corroborees or rock art indicates that the area had a particular significance to them.

A short distance (south) down the Derwent River from this spot, stencilled hands on the walls of a sandstone cave have been recorded by Dr. Bryden and S. de Teliga. There is some dissimilarity between these rock carvings and those on Tasman's Peninsula. Here is one of the first examples of what appears to be a corroboree (fig. 3). There are several figures of a similar kind where objects seem to be moving in procession or chain formation.

FIG. 5.—The large irregular figure probably represents some four-legged creature such as a lizard or a kangaroo. It is approximately 6" long and ¼" deep.

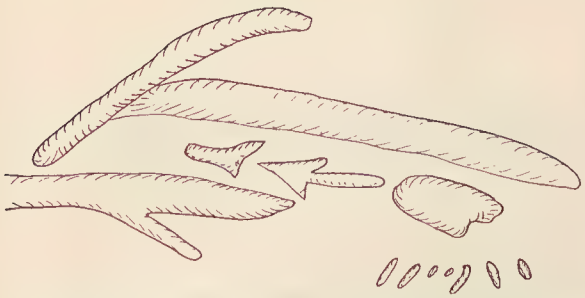

FIG. 6.—These markings have the appearance of large scratches such as could be made by the rubbing of spear points for sharpening. The longest figure is approximately 4" long and 3/16" deep. Note the bird track.

The largest engraving is a three-feet curve with a depth up to two inches. Its significance is obscure. These newly recorded rock engravings are, however, in general conformity with others found to date in southern Tasmania.

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# ON THE NOMENCLATURE OF PTERUCHUS JOHNSTONI (FEISTMANTEL) COM. NOV.

By

John A. Townrow.

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(With one figure.)

## ABSTRACT

The holotype of the species hitherto called *Pteruchus africanus* Thomas is redescribed and refigured; on grounds of priority this species must now be called *Pteruchus johnstoni* (Feistmantel) com. nov. The specimen named *Stachyopitys annularioides* Shirley is redescribed and considered to be identical with *P. johnstoni.*

## INTRODUCTION.

The type species of the genus *Pteruchus* has hitherto been called *Pteruchus africanus* Thomas (1933), but Thomas and others (Jones and de Jersey 1947, Townrow, 1961) have pointed out that certain specimens described earlier might be identical with *P. africanus,* and if so, that the earliest of their names might have priority. These specimens are as follows:—

1. *Sphenolepis rhaetica* Geinitz, 1876, p. 12, pl. 2 figs. 23, 24. (Location of specimen unknown.)
2. "Male flower of *Baiera tenuifolia*" Johnston, 1888, pl. 27 figs. 2D and E (see also Feistmantel, 1890, p. 113, pl. 10, fig. 5; and Walkom, 1924, pp. 85-86, figs. 15, 16). (Tasmanian Museum: No. B 1049.)
3. *Stachyopitys annularioides* Shirley, 1898, p. 13, pl. 18, fig. 1. (Geological Survey of Queensland: No. F. 142.)

Thanks to the kindness of the Director, the Tasmanian Museum, and the the Government Geologist, Geological Survey of Queensland, I have been able to examine Johnston's and Shirley's specimens.

Geinitz's specimen is indeterminable from his figure. Until the specimen is re-examined his name *Sphenolepis rhaetica* must be written off as a *nomen vanum,* a name applied to an indeterminable type.

## DESCRIPTION AND DISCUSSION

(i) *Johnston's specimen*: *Tasmanian Museum* B 1049. Sporophyll 2.5 cms. long, base not seen, rachis maximum width 2 mm., four alternate pinnae present, but no vegetative pinnules. Pinnae expanding into more or less round sporangial heads, preserved sporangial surface uppermost. Diameter (including projecting pollen sacs) about 5 mm. (largest 8 x 6 mm.). Pollen sacs very close set, at least 30 per head, about 2 mm. long and 1 mm. wide, slightly inflated, apex bluntly pointed, dehiscing by a longitudinal slit flanked by narrow cells. Rachis showing imprints of cells comprising a wing of narrow cells (about 150$\mu$ x 35$\mu$), and a central band of wider cells with stomata, measuring about 180$\mu$ x 70$\mu$. Pollen sac impressions showing imprints of elongated cells about 250$\mu$ x 74$\mu$. No cuticle or pollen preserved.

This specimen was first figured by Johnston (1888), but he did not give a name, believing it to be attached to a specimen of the leaf *Czekanowskia* (originally *Baiera*) *tenuifolia.* Feistmanted (1890) gives another figure and also a name, *Trichopitys johnstoni.* He also believed the pollen organ and leaf to be attached. Walkom (1924) pointed out that the leaf and pollen organ are not joined, but he accepted the view that they belong to the same plant and he also reverted to Johnston's nomenclature.

Walkom was correct; the leaf and pollen organ are not joined. They not only lie at different levels in the rock but point in opposite directions, see fig. 1A. There are, indeed, no grounds except association for believing that the two fossils have anything to do with one another. The leaf itself I cannot identify. It probably is *C. tenuifolia,* but it could be a specimen of *Xylopteris* (older name *Stenopteris*) *elongata,* which is probably present in the Lord's Hill locality (see Johnston, 1888, pl. 27, fig. 7).

Specimen B 1049 agrees in every available feature, including such cellular detail as is visible, with better preserved material called *Pteruchus africanus,* and differs distinctly from the other two species, *P. dubius* and *P. simmondsi.* It is therefore identified. Feistmantel's name is the earliest given to the pollen organ as such, and therefore becomes the specific name for the species, and the specimen B 1049 becomes the holotype.

The record has additional interest in that it is another record of association between *Pteruchus johnstoni* and the leaf *Dicroidium odontopteroides,* since it has been suggested (Townrow, 1961) that these two fossils are parts of the same plant. *D. odontopteroides* is recorded from Lord's Hill, and is present on B 1049.

(ii) *Shirley's specimen*: *Geological Survey of Queensland* F 142. This specimen which lacks a counterpart and is an impression only, shows the remains of at least two sporophylls. The surface of the fossil is very uneven, and I think there is little doubt that the specimen has split through the plant material (or the space left by its absence) leaving about equal quantities on part and counter part, though in the absence of the counterpart this cannot be confirmed. No sporangial heads are complete, the most complete show the remains of about 25 pollen sacs, so the original number was probably greater than this.

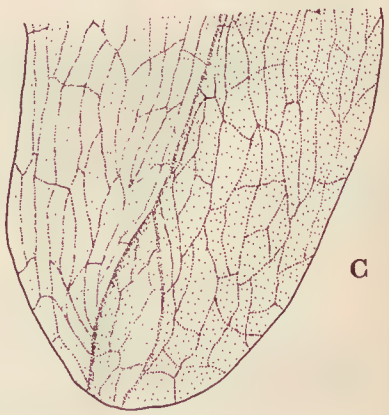
The number of pollen sacs is an important point, for the only definite difference between *P. johnstoni* and *P. annularioides* is that the latter was suposed to have fewer pollen sacs per head. It now appears the number of pollen sacs is about the same.

In dimensions, in showing the cast of a strongly rugose non-sporangial surface of the head, and so far as visible, in size and form of the cellular impressions, this specimen agrees with the holotype of *P. johnstoni,* and is united with it, the name *annularioides* becoming a synonym. Besides Shirley's specimen only two other fossils have been called *Pteruchus* (or *Stachyopitys*) *annularioides.* They are in Jones and de Jersey (1947) text-fig. 38, which is hardly identifiable, and in Halle (1913), pl. 6, figs. 13, 13a, which is probably distinct.

## CITATION AND HOLOTYPE

1888 Male flower of *Baiera tenuifolia* Johnston, pl. 27, figs. 2D and E (figs. 2C and 2B distinct).
1890 *Trichopitys johnstoni* Feistmantel, p. 113, pl. 10, fig. 5. (Johston's specimen refigured.)
1898 *Stachyopitys annulariodies* Shirley, p. 13, pl. 18, fig. 1.
1933 *Pteruchus africanus* Thomas, pp. 235-237, pl. 24, figs. 71, 72, text-figs. 34, 35.
1961 *Pteruchus africanus* Thomas: Townrow, pp. 293-296, pl. 24, fig. 4, pl. 25, figs. 1, 2, pl. 26, figs. 2, 4-11; text figs. 1-3, 6-10.
(Diagnosis and full synonomy given.)
Holotype: Tasmanian Museum B 1049.
Locality: Lord's Hill, Hobart, Tasmania.
Horizon and Age: Feldspathic Sandstone Series, Triassic.
Collector: R. M. Johnston, in about 1880.

*Emended Diagnosis.* Microsporophyll about 2 cms. long, rachis about 1.5 mm. wide at base. About eight (4-9) long, normally unbranched pinnae present. Heads round to about four times as long as wide, width about 5 mm., non-sporangial surface strongly rugose, about 10 lobes per head, lobes small in proportion to size of head. Pollen sacs 30 or more per head, about 2.5 mm. long and 1.5 mm. wide. Cell outlines faint, 1$\mu$ or less, sinuosities small, sometimes absent, about 1$\mu$ long, usually obtuse, not pointed. Stomata somewhat sunken, poles exposed, pit not overlapped by cutin flanges. Pollen bisaccate, corpus normally deeper than wide, rarely rounded (polar view). Aposaccale areas (polar view) obtuse or bluntly pointed, grain as high as wide, or higher, outline trapezoid. Cappa convex, other surfaces more or less flat. Roots of sacci markedly offset distally, proximal roots normally inserted distally to widest part of corpus. Sacci as deep as corpus, or a little less, often slightly




LEGEND FOR FIGURES.

A. The holotype B 1049. Tasmanian Museum. X 2-5.
B. Imprints of cells and stomata from the rachis B 1049/X 120.
C. Imprints of cells and the dehiscena slit on a sporangium B 1049 X 120.

inflated. Ornament on sacci: brochi ca. 3$\mu$ in diameter, muri ca 1$\mu$ wide. Cappa normally slightly uneven, sometimes thickened (up to ca 2$\mu$). Dimensions (fiducial limits bracketed): corpus depth 45.3$\mu$ (3.56), width 32.2$\mu$ (3.70); width of total grain 62$\mu$ (3.51); height of sacci 35.5$\mu$ (1.88).

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# ALLOTHUNNUS FALLAI SERVENTY—A NEW RECORD FOR AUSTRALIAN WATERS

By

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## ABSTRACT

The capture of two specimens of *Allothunnus fallai* Serventy in Pirates Bay, Tasmania, constitutes the first record of this rare tuna in Australian waters. Four of these tuna have been taken from waters within latitudes 43° and 44° S. Biometrical data are given of two fish.

## INTRODUCTION.

In July, 1960, the first two tuna, while splashing in a distressed manner, were caught by hand in shallow water at the southern end of Pirates Bay, Tasman Peninsula. The first specimen, weighing about 30 lb., was eaten and the second (18.5 lb.) was made available for study.

In January, 1961, a third specimen was caught on a tow line off Pedra Blanca, a rocky islet about 20 miles off the southern coast of Tasmania. Captain R. J. Downie, formerly master, C.S.I.R.O. Fisheries Research Vessel "Derwent Hunter", who trolled the tuna, recognised it as different from other tuna he had seen and before dissecting it made a series of measurements of the tuna. He had no means of preserving the fish for later detailed study.

The fourth specimen was caught in a set net in four fathoms in Pirates Bay near the same locality where the first two tuna were caught just over a year earlier.

## DESCRIPTION

*Colour*: In this respect Falla's tuna bears a superficial resemblance to the southern bluefin tuna *Thunnnus thynnus maccoyii* (Castelnau): the dorsal surface is dark-blue, and the ventral surface silvery. There is no evidence of any pattern.

A circular non-pigmented area, 1-1.5 cm. diameter, was present on the heads of the two tuna examined. This clear area lies in a median position immediately in front of the supra-occipital crest and the anterior edge is closer to the snout than the posterior edge of the eye. Immediately beneath the clear area is a fontanelle, an unossified part of the cranium. In the fresh state it was reported that this tuna had "a window on its brain".

The caudal keels are whitish in colour and appear semi-transparent.

*Scales*: The *corselet* is well defined in the pectoral region, the scales decreasing in size towards the dorsal caudal region. There were no signs of scales on the ventral caudal region of the 83 cm. fish.

In all other external characters there is close agreement with the original description given by Serventy (1948).

*Internal Anatomy.*

There was no swim bladder.

Pyloric caeca were numerous and extended approximately two-thirds of the length of the body cavity.

Gall bladder was thin walled, approximately 1 cm. diameter and extended about two-thirds of the length of the body cavity.

Stomach had only 13 prominent longitudinal ridges whereas the New Zealand specimen had 16 ridges.

Gonads (male) extended forwards into the posterior half of the body cavity; they were whitish in colour, firm in texture and mature.

Liver was folded around the alimentary canal, the left lobe being larger and longer than the right lobe. In the tuna caught by him, Captain Downie reported:—

*Liver*: Large with elongated dark lobe.

*Stomach contents*: Krill.

*Pyloric caeca*: Large.

No swim bladder apparent.

*Sex*: Female, stage 3.

*Flesh*: Greenish in colour, oily in texture.

After thawing following cold storage for over a year, oil was present on the surface of the 83 cm. tuna from Pirates Bay.

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## MEASUREMENTS (cm.) OF *ALLOTHUNNUS FALLAI* CAUGHT IN SOUTHERN TASMANIAN WATERS.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Location of capture | Pirates Bay | Pirates Bay | Pedra Blanca | Pirates Bay |
| Date | July 1, 1960 | July 1, 1960 | Jan. 16, 1961 | August 9, 1961 |
| Person | R. Pettman | R. Pettman | R. J. Downie | C. Pettman |
| Method | Stranded | Stranded | Tow line | Set net |
| Total length | 85 | .. | c. 76 | 96.5 |
| Total weight | 18.5 lb. | c. 30 lb. | c. 22 lb. | 15 lb. |
| Sex | Male | ... | Female | .... |
| Fin formulae:— | | | | |
| Dorsal | 15, 12, 7 | .... | 15, —, 7 | .... |
| Anal | 14, 7 | .... | —, 7 | .... |
| Pectoral | 25 | .... | — | .... |
| Gill raker count: 1st arch | left 77, right 76 | .... | 66 + | 77 |
| Length— | | | | |
| Snout to caudal fork | 80.0 | .... | .... | |
| Head length | 20.5 | .... | .... | 23.0 |
| Origin of pectoral fin | 21.5 | .... | .... | .... |
| Origin of 1st dorsal fin | 24.2 | .... | .... | .... |
| Origin of 2nd dorsal fin | 49.2 | .... | .... | |
| Origin of ventral fin | 22.0 | .... | .... | .... |
| To anterior edge of vent | 50.5 | .... | .... | .... |
| Hinder edge of pre-operculum | 15.5 | .... | .... | 17.4 |
| Anterior nostril | 3.7 | .... | ... | 3.8 |
| Posterior nostril | 5.2 | .... | .... | 5.8 |
| Anterior edge of eye | 5.8 | .... | .... | 6.5 |
| Anterior edge of median non-pigmented area | 6.5 | .... | .... | 8.0 |
| Posterior edge of median non-pigmented area | 7.5 | .... | .... | 9.5 |
| Diameter of eye | 3.0 | .... | .... | 3.3 |
| Inter-orbital diameter | 5.5 | .... | .... | 7.0 |
| Inter-axillary diameter | 12.0 | .... | .... | .... |
| Length of pectoral fin | 8.0 | .... | .... | .... |
| Length of pectoral fin alongside body | 9.5 | .... | .... | .... |
| Length of maxillary | 7.2 | .... | .... | 8.0 |
| Length of mandible | 7.0 | .... | .. . | 8.0 |
| Height of body at origin of 1st dorsal fin | 17.0 | ... | ... | .... |
| Greatest height of body | 18.0 | .... | . . | .... |
| Height of body at vent | 16.0 | .... | ... | .... |
| Height of 1st dorsal fin | 7.5 | .... | .. . | ....t |
| Height of 2nd dorsal fin | 7.5 | .... | ... | .... |
| Height of anal fin | 7.2 | .... | ... | .... |
| Height of upper caudal lobe | 12.0 | .... | .. | Head only available |

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